User's Manual

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RX62T Group

User's Manual: Hardware

RENESAS 32-Bit MCU
RX Family / RX600 Series

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General Precautions in the Handling of MPU/MCU Products

The following usage notes are applicable to all MPU/MCU products from Renesas. For detailed usage notes on the products covered by this manual, refer to the relevant sections of the manual. If the descriptions under General Precautions in the Handling of MPU/MCU Products and in the body of the manual differ from each other, the description in the body of the manual takes precedence.

1. Handling of Unused Pins

   Handle unused pins in accord with the directions given under Handling of Unused Pins in the manual.

   — The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible. Unused pins should be handled as described under Handling of Unused Pins in the manual.

2. Processing at Power-on

   The state of the product is undefined at the moment when power is supplied.

   — The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the moment when power is supplied.

   In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the moment when power is supplied until the reset process is completed.

   In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the moment when power is supplied until the power reaches the level at which resetting has been specified.

3. Prohibition of Access to Reserved Addresses

   Access to reserved addresses is prohibited.

   — The reserved addresses are provided for the possible future expansion of functions. Do not access these addresses; the correct operation of LSI is not guaranteed if they are accessed.

4. Clock Signals

   After applying a reset, only release the reset line after the operating clock signal has become stable. When switching the clock signal during program execution, wait until the target clock signal has stabilized.

   — When the clock signal is generated with an external resonator (or from an external oscillator) during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Moreover, when switching to a clock signal produced with an external resonator (or by an external oscillator) while program execution is in progress, wait until the target clock signal is stable.

5. Differences between Products

   Before changing from one product to another, i.e. to one with a different part number, confirm that the change will not lead to problems.

   — The characteristics of MPU/MCU in the same group but having different part numbers may differ because of the differences in internal memory capacity and layout pattern. When changing to products of different part numbers, implement a system-evaluation test for each of the products.

How to Use This Manual

1. Objective and Target Users

This manual was written to explain the hardware functions and electrical characteristics of this LSI to the target users, i.e. those who will be using this LSI in the design of application systems. Target users are expected to understand the fundamentals of electrical circuits, logic circuits, and microcomputers.
This manual is organized in the following items: an overview of the product, descriptions of the CPU, system control functions, and peripheral functions, electrical characteristics of the device, and usage notes.

When designing an application system that includes this LSI, take all points to note into account.
Points to note are given in their contexts and at the final part of each section, and in the section giving usage notes.

The list of revisions is a summary of major points of revision or addition for earlier versions. It does not cover all revised items. For details on the revised points, see the actual locations in the manual.

The following documents have been prepared for the RX62T Group. Before using any of the documents, please visit our web site to verify that you have the most up-to-date available version of the document.

Document Type	Contents	Document Title	Document No.
Short Sheet	Overview of hardware	—	—
Data Sheet	Overview of hardware and electrical characteristics	RX62T Group Data Sheet	—
User's manual: Hardware	Hardware specifications (pin assignments, memory maps, peripheral specifications, electrical characteristics, and timing charts) and descriptions of operation	RX62T Group User's manual: Hardware	This User's manual
User's manual: Software	Detailed descriptions of the CPU and instruction set	RX Family Series User's manual: Software	REJ09B0435
Application Note	Examples of applications and sample programs	—	—
Renesas Technical Update	Preliminary report on the specifications of a product, document, etc.	—	—

2. Description of Registers

Each register description includes a bit chart, illustrating the arrangement of bits, and a table of bits, describing the meanings of the bit settings. The standard format and notation for bit charts and tables are described below.

X.X.X ... Register

Address xxxx xxxxxh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	...	...	...	—	—	—	...
Value after reset	X	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	... 0	... Bit	0: ..... 1: Setting prohibited (3)	R/W (1)
b3 to b1	—	Reserved (2)	The read value is 0. The write value should always be 0.	R/W
b4	... 4	... Bit	0: 1:	R
b6, b5	... [1:0]	... Bi	0 0: ..... 0 1: ..... Settings other than above are prohibited. (3)	R/(W)*
b7	—	Reserved	The read value is undefined. Writing to this bit has no effect.	R

(1) R/W: The bit or field is readable and writable.
R/(W): The bit or field is readable and writable. However, writing to this bit or field has some limitations. For details on the limitations, see the description or notes of respective registers.
R: The bit or field is readable. Writing to this bit or field has no effect.

(2) Reserved. Make sure to use the specified value when writing to this bit or field; otherwise, the correct operation is not guaranteed.

(3) Setting prohibited. The correct operation is not guaranteed if such a setting is performed.

3. List of Abbreviations and Acronyms

Abbreviation	Full Form
ACIA	Asynchronous Communication Interface Adapter
bps	bits per second
CRC	Cyclic Redundancy Check
DMA	Direct Memory Access
DMAC	Direct Memory Access Controller
GSM	Global System for Mobile Communications
Hi-Z	High Impedance
IEBus	Inter Equipment Bus
I/O	Input / Output
IrDA	Infrared Data Association
LSB	Least Significant Bit
MSB	Most Significant Bit
NC	Non-Connect
PLL	Phase Locked Loop
PWM	Pulse Width Modulation
SIM	Subscriber Identity Module
UART	Universal Asynchronous Receiver / Transmitter
VCO	Voltage Controlled Oscillator

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100-MHz 32-bit RX MCUs, FPU, 165 DMIPS, 12-bit ADC (3 S/H circuits, double data register, amplifier, comparator): two units, 10-bit ADC one unit, the three ADC units are capable of simultaneous 7-ch. sampling, 100-MHz PWM (two three-phase complementary channels and four single-phase complementary channels or three three-phase complementary channels and one single-phase complementary channel)

Features

■ 32-bit RX CPU core
- Max. operating frequency: 100 MHz
  Capable of 165 DMIPS in operation at 100 MHz
- Single precision 32-bit IEEE-754 floating point
- Accumulator handles 64-bit results (for a single instruction) from 32- × 32-bit operations
- Multiplication and division unit handles 32- × 32-bit operations (multiplication instructions take one CPU clock cycle)
- Fast interrupt
- Divider (fastest instruction execution takes two CPU clock cycles)
- Fast interrupt
- CISC Harvard architecture with 5-stage pipeline
- Variable-length instructions: Ultra-compact code
- Supports the memory protection unit (MPU)
- Background JTAG debugging plus high-speed tracing

■ Operating voltage
- Single 3.3- or 5-V supply; 5-V analog supply is possible with 3.3-V products

■ Low-power design and architecture
- Four low-power modes

■ On-chip main flash memory, no wait states
- 100-MHz operation, 10-ns read cycle
- No wait states for reading at full CPU speed
- 64-Kbyte/128-Kbyte/256-Kbyte capacities
- For instructions and operands
- User code programmable via the SCI or JTAG

■ On-chip data flash memory
- Max. 32 Kbytes, reprogrammable up to 30,000 times
- Erasing and programming impose no load on the CPU.

■ On-chip SRAM, no wait states
- 8-Kbyte/16-Kbyte SRAM
- For instructions and operands

■ DMA
- DTC: The single unit is capable of transfer on multiple channels

■ Reset and supply management
- Power-on reset (POR)
- Low voltage detection (LVD) with voltage settings

■ Clock functions
- External crystal oscillator or internal PLL for operation at 8 to 12.5 MHz
- Internal 125-kHz LOCO for the IWDT
- Detection of main oscillator stoppage (for IEC 60730 compliance)

■ Independent watchdog timer (for IEC60730compliance)
- 125-kHz LOCO clock operation
- Software is incapable of stopping the robust WDT.

PLQP0112JA-A 20×20mm, 0.65mm pitch
PLQP0100KB-A 14×14mm, 0.5mm pitch
PLQP0080JA-A 14×14mm, 0.65mm pitch
PLQP0064KB-A 10×10mm, 0.5mm pitch
PLQP0064GA-A 14x14 mm, 0.8mm pitch

■ Up to 7 communications interfaces
- 1: CAN (compliant with ISO11898-1), incorporating 32 mailboxes
- 3: SCIs, with asynchronous mode (incorporating noise cancellation), clock-synchronous mode, and smart-card interface mode
- 1: I2C bus interface, capable of SMBus operation
- 1: RSPI
- 1: LIN

■ Up to 16 16-bit timers
- 8: 16-bit MTU3: 100-MHz operation, input capture, output compare, two three-phase complementary PWM output channels, complementary PWM imposing no load on the CPU, phase-counting mode
- 4: 16-bit GPT: 100-MHz operation, input capture, output compare, four complementary single-phase PWM output channels, or one three-phase complementary PWM output channel and one single-phase complementary PWM output channel, complementary PWM imposing no load on the CPU, operation linked with comparator (for counting and control of PWM-signal negation), detection of abnormal oscillation frequencies (for IEC 60730 compliance)
- 4: 16-bit CMT

■ Three A/D converter units for 1-MHz operation, for a total of 20 channels
- Three units are capable of simultaneous sampling on seven channels
- Self diagnosis (for IEC60730 compliance)
- 8: Two 12-bit ADC units: three sample-and-hold circuits, double data registers, amplifier, comparator
- 12: Single 10-bit ADC unit

■ CRC (cyclic redundancy check) calculation unit
- Monitoring of data being transferred (for IEC 60730 compliance)
- Monitoring of data in memory (for IEC 60730 compliance)

■ Up to 61 input–output ports and up to 21 input-only ports
- PORT registers: Monitoring of output ports (for IEC 60730 compliance)

■ Operating temp. range
- –40°C to +85°C

1. Overview

1.1 Features

The RX62T Group is a set of MCUs featuring the high-speed, high-performance RX CPU as the processor core.
Each basic instruction of the processor is executable in one cycle of the system clock. Calculation functionality is enhanced by the inclusion of a single-precision floating-point calculation unit as well as a 32-bit multiplier and divider. Additionally, code efficiency is improved by instructions with lengths that are variable in byte units to cover an enhanced range of addressing modes.
A multi-functional timer pulse unit 3 (for motor control), general PWM timer, compare match timers, watchdog timer, independent watchdog timer, serial communications interfaces, I^2C bus interfaces, CAN module, serial peripheral interface, LIN module, 12-bit A/D converters with three-channel simultaneous sampling function, and 10-bit A/D converter are incorporated as peripheral functions which are essential to motor control devices. In addition, the 12-bit A/D converters include a window comparator and programmable gain amplifier for additional functionality.
Large-capacity flash memory units capable of high-speed operation are included as on-chip memory, significantly reducing the cost of configuring systems.

1.1.1 Applications

Industrial equipment, household electrical appliances, machines requiring motor control, and inverter-powered machines

1.1.2 Outline of Specifications

Table 1.1 lists the specifications in outline, and Table 1.2 lists the functions of products.

Table 1.1 Outline of Specifications (1 / 5)

Classification	Module/Function	Description
CPU	CPU	• Maximum operating frequency: 100MHz • 32-bit RX CPU • Minimum instruction execution time: One instruction per state (cycle of the system clock) • Address space: 4-Gbyte linear • Register set of the CPU • General purpose: Sixteen 32-bit registers • Control: Nine 32-bit registers • Accumulator: One 64-bit register • Basic instructions: 73 • Floating-point instructions: 8 • DSP instructions: 9 • Addressing modes: 10 • Data arrangement • Instructions: Little endian • Data: Selectable as little endian or big endian • On-chip 32-bit multiplier: 32 x 32 → 64 bits • On-chip divider: 32 / 32 → 32 bits • Barrel shifter: 32 bits • Memory-protection unit (MPU)
	FPU	• Single precision (32-bit) floating point • Data types and floating-point exceptions in conformance with the IEEE754 standard
Memory	ROM	• ROM capacity: 256 Kbytes (max.) • Two on-board programming modes • Boot mode (The user MAT is programmable via the SCI) • User program mode • Off-board programming • A PROM programmer can be used to program the user mat.
	RAM	• RAM capacity: 16 Kbytes (max.)
	Data flash	• Data flash capacity: 32 Kbytes (max.) • Supports background operations (BGO)
MCU operating mode		• Single-chip mode
Clock	Clock generation circuit	• One circuit: Main clock oscillator • Internal oscillator: Low-speed on-chip oscillator dedicated to IWDT • Structure of a PLL frequency synthesizer and frequency divider for selectable operating frequency • Oscillation stoppage detection • Independent frequency-division and multiplication settings for the system clock (ICLK) and peripheral module clock (PCLK) • The CPU and system sections such as other bus masters, MTU3, and GPT run in synchronization with the system clock (ICLK): 8 to 100 MHz. • Peripheral modules run in synchronization with the peripheral module clock (PCLK): 8 to 50 MHz
Reset		Pin reset, power-on reset (automatic power-on reset when the power is turned on), voltage-monitoring reset, watchdog timer reset, independent watchdog timer reset, and deep software standby reset
Voltage detection circuit (LVD)		When the voltage on VCC falls below the voltage detection level (Vdet), an internal reset or internal interrupt is generated.
Low power consumption	Low power consumption facilities	• Module stop function • Four low power consumption modes • Sleep mode, all-module clock stop mode, software standby mode, and deep software standby mode
Interrupt	Interrupt controller (ICU)	• Peripheral function interrupts: 101 sources • External interrupts: 9 (NMI and IRQ0 to IRQ7 pins) • Non-maskable interrupts: 3 (the NMI pin, oscillation stop detection interrupt, and voltage-monitoring interrupt) • 16 levels specifiable for the order of priority

Table 1.1 Outline of Specifications (2 / 5)

Classification	Module/Function	Description
Data transfer	Data transfer controller (DTC)	• Three transfer modes: Normal transfer, repeat transfer, and block transfer • Activation sources: Software trigger, external interrupts, and interrupt requests from peripheral functions
I/O ports	Programmable I/O ports	I/O port pins for devices in the 112-pin LQFP/100-pin LQFP/80-pin LQFP/64-pin LQFP • I/O: 61/55/44/37 • Input only: 21/21/13/9 • Open-drain outputs: 2/2/2/2 (I^2C bus interface pins) • Large-current outputs: 12/12/6/6(0) (MTU3 and GPT pins) The 5-V version of the 64-pin product does not have large-current outputs. • Reading out the states of pins is always possible.
Timers	Multi-function timer pulse unit 3 (MTU3)	• 16 bits x 8 channels • Up to 24 pulse inputs/outputs and three pulse inputs • Select from among six to eight counter-input clock signals for each channel (ICLK/1, ICLK/4, ICLK/16, ICLK/64, ICLK/256, ICLK/1024, MTCLKA, MTCLKB, MTCLKC, MTCLKD) other than channel 5, for which only four signals are available. • 24 output compare or input capture registers • Counter clearing (clearing is synchronizable with compare match or input capture) • Simultaneous writing to multiple timer counters (TCNT) • Input to and output from all registers in synchronization with counter operation • Buffered operation • Cascade-connected operation • 38 kinds of interrupt source • Automatic transfer of register data • Pulse output modes Toggled, PWM, complementary PWM, and reset synchronous PWM • Complementary PWM output mode Outputs non-overlapping waveforms for controlling 3-phase inverters Automatic specification of dead times PWM duty cycle: Selectable as any value from 0% to 100% Delay can be applied to requests for A/D conversion. Non-generation of interrupt requests at peak or trough values of counters can be selected. Double buffering • Reset-synchronous PWM mode Three PWM waveforms and corresponding inverse waveforms are output with the desired duty cycles. • Phase-counting mode • Counter functionality for dead-time compensation • Generation of triggers for A/D converters • Differential timing for initiation of A/D conversion
	Port output enable 3 (POE3)	• Control of the high-impedance state of the MTU3 and GPT's waveform output pins 5 pins for input from signal sources: POE0, POE4, POE8, POE10, POE11 Initiation on detection of short-circuited outputs (detection of simultaneous switching of large-current pins to the active level) Initiation by comparator-detection of analog level input to the 12-bit A/D converter Initiation by oscillation-stoppage detection Initiation by software • Selection of which output pins should be placed in the high-impedance state at the time of each POE input or comparator detection

Table 1.1 Outline of Specifications (3 / 5)

Classification	Module/Function	Description
Timers	General PWM timer (GPT)	• 16 bits x 4 channels • Counting up or down (saw-wave), counting up and down (triangle-wave) selectable for all channels • Clock sources independently selectable for all channels • 2 input/output pins per channel • 2 output compare/input capture registers per channel • For the 2 output compare/input capture registers of each channel, 4 registers are provided as buffer registers and are capable of operating as comparison registers when buffering is not in use. • In output compare operation, buffer switching can be at peaks or troughs, enabling the generation of laterally asymmetrically PWM waveforms. • Registers for setting up frame intervals on each channel (with capability for generating interrupts on overflow or underflow) • Synchronizable operation of the several counters • Modes of synchronized operation (synchronized, or displaced by desired times for phase shifting) • Generation of dead times in PWM operation • Through combination of three counters, generation of automatic three-phase PWM waveforms incorporating dead times • Starting, clearing, and stopping counters in response to external or internal triggers • Internal trigger sources: output of the internal comparator detection, software, and compare-match • The frequency-divided system clock (ICLK) can be used as a counter clock for measuring timing of the edges of signals produced by frequency-dividing the low-speed on-chip oscillator clock signal dedicated to IWDT (to detect abnormal oscillation).
	Compare match timer (CMT)	• (16 bits x 2 channels) x 2 units • Select from among four internal clock signals (PCLK/8, PCLK/32, PCLK/128, PCLK/512)
	Watchdog timer (WDT)	• 8 bits x 1 channel • Select from among eight counter-input clock signals (PCLK/4, PCLK/64, PCLK/128, PCLK/512, PCLK/2048, PCLK/8192, PCLK/32768, PCLK/131072) • Switchable between watchdog timer mode and interval timer mode
	Independent watchdog timer (IWDT)	• 14 bits x 1 channel • Counter-input clock: low-speed on-chip oscillator dedicated to IWDT
Communications	Serial communications interface (SCIb)	• 3 channels • Serial communications modes: Asynchronous, clock synchronous, and smart-card interface • Multiprocessor communications • On-chip baud rate generator allows selection of the desired bit rate • Choice of LSB-first or MSB-first transfer • Noise cancellation (only available in asynchronous mode)
	I^2C bus interface (RIIC)	• 1 channel • Communications formats I^2C bus format/SMBus format Master/slave selectable

Table 1.1 Outline of Specifications (4 / 5)

Classification	Module/Function	Description
Communications	CAN module (CAN) (as an optional function)	• 1 channel • 32 mailboxes
	Serial peripheral interface (RSPI)	• 1 unit • RSPI transfer facility Using the MOSI (master out, slave in), MISO (master in, slave out), SSL (slave select), and RSPI clock (RSPCK) signals enables serial transfer through SPI operation (four lines) or clock-synchronous operation (three lines) Capable of handling serial transfer as a master or slave • Data formats Switching between MSB first and LSB first The number of bits in each transfer can be changed to any number of bits from 8 to 16, or to 20, 24, or 32 bits. 128-bit buffers for transmission and reception Up to four frames can be transmitted or received in a single transfer operation (with each frame having up to 32 bits) • Buffered structure • Double buffers for both transmission and reception
	LIN module (LIN)	• 1 channel (LIN master) • Supports revisions 1.3, 2.0, and 2.1 of the LIN protocol
A/D converter	12-bit A/D converter (S12ADA)	• 12 bits (2 units x 4 channels) • 12-bit resolution • Conversion time: 1.0 μs per channel (in operation with A/D conversion clock ADCLK at 50 MHz) for AVCC = 4.0 to 5.5 V 2.0 μs per channel (in operation with A/D conversion clock ADCLK at 25 MHz) for AVCC0 = 3.0 to 3.6 V • Two basic operating modes Single mode and scan mode • Scan mode One-cycle scan mode Continuous scan mode 2-channel scan mode (Input ports of the A/D unit are divided into two groups in this mode, and the activation sources are separately selectable for each group.) • Sample-and-hold function A common sample-and-hold circuit for both units is included. Additionally, sample-and-hold circuit for each unit is included. (three channels per unit) • A/D-conversion register settings for each input pin. • Two registers for the result of conversion are provided for a single analog input pin of each unit (AN000 and AN100). • Three ways to start A/D conversion Conversion can be started by software, a conversion start trigger from a timer (MTU3 or GPT), or an external trigger signal. • Functionality for 8- or 10-bit precision output Right-shifting of the results of conversion for output by two or four bits is selectable. • Self-diagnostic function The self-diagnostic function internally generates three analog input voltages (VREFL0, VREFH0 x 1/2, VREFH0). • Amplification of input signals by a programmable gain amplifier (three channels per unit) Amplification rate: 2.0-, 2.5-, 3.077-, 3.636-, 4.0-, 4.444-, 5.0-, 5.714-, 6.667-, 10.0-, or 13.333-times amplification (a total of 11 steps) • Window comparators (three channels per unit)

Table 1.1 Outline of Specifications (5 / 5)

Classification	Module/Function	Description
A/D converter	10-bit A/D converter (ADA)	• 10 bits (1 unit x 12 channels) • 10-bit resolution • Conversion time: 1.0 μs per channel (in operation with A/D conversion clock ADCLK at 50 MHz) for AVCC0 = 4.0 to 5.5 V 2.0 μs per channel (in operation with A/D conversion clock ADCLK at 25 MHz) for AVCC = 3.0 to 3.6 V • Two basic operating modes Single mode and scan mode • Scan mode One-cycle scan mode Continuous scan mode • Sample-and-hold function A common sample-and-hold circuit for both units is included. • A/D-conversion register settings for each input pin • Three ways to start A/D conversion Conversion can be started by software, a conversion start trigger from a timer (MTU3 or GPT), or an external trigger signal. • Functionality for 8-bit precision output Right-shifting the results of conversion for output by two bits is selectable. • Self-diagnostic function The self-diagnostic function internally generates three analog input voltages (AVSS, VREF x 1/2, VREF).
CRC calculator (CRC)		• CRC code generation for arbitrary amounts of data in 8-bit units • Select any of three generating polynomials: $X^8 + X^2 + X + 1$, $X^{16} + X^{15} + X^2 + 1$, or $X^{16} + X^{12} + X^5 + 1$. • Generation of CRC codes for use with LSB-first or MSB-first communications is selectable.
Operating frequency		ICLK: 8 to 100 MHz PCLK: 8 to 50 MHz
Power supply voltage		• 3-V version VCC = PLLVCC = 2.7 to 3.6V AVCC0 = AVCC = 3.0 to 3.6V, or 4.0 to 5.5V VREFH0 = 3.0 to AVCC0, or 4.0 to AVCC0 VREF = 3.0 to AVCC, or 4.0 to AVCC • 5-V version VCC = PLLVCC = 4.0 to 5.5V AVCC0 = AVCC = 4.0 to 5.5V VREFH0 = 4.0 to AVCC0 VREF = 4.0 to AVCC
Operating temperature		–40 to +85°C
Packages		112-pin LQFP (PLQP0112JA-A, 20x20-0.65-mm pitch) 100-pin LQFP (PLQP0100KB-A, 14x14-0.5-mm pitch) 80-pin LQFP (PLQP0080JA-A, 14x14-0.65-mm pitch) 64-pin LQFP (PLQP0064KB-A, 10x10-0.5-mm pitch) 64-pin LQFP (PLQP0064GA-A, 14x14-0.8mm pitch)

Table 1.2 Functions of RX62T Group Products

Functions		RX62T Group			
Pin number		**112 Pin**	**100 Pin**	**80 Pin**	**64 Pin**
Data transfer	Data transfer controller (DTC)	O			
Interrupt controller (ICU)	Input on the NMI pin	O			
	Input on the IRQ pins	O (8)			O (4)
Timers	Multi-function timer pulse unit 3 (MTU3)	O		O*	
	General PWM timer (GPT)	O		O*	
	Port output enable 3 (POE3)	O (POE pins: 5)		O (POE pins: 3)	
	Compare match timer (CMT)	O			
	Watchdog timer (WDT)	O			
	Independent watchdog timer (IWDT)	O			
Communication function	Serial communications interface (SCI)	O			
	I^2C bus interface (RIIC)	O			
	CAN module (CAN) (as an optional function)	O			
	LIN module (LIN)	O			
	Serial peripheral interface (RSPI)	O			
12-bit A/D converter (S12ADA)		O (4 ch. x 2 units)			
	Simultaneous sampling on three channels	O (2 units)			
	Programmable gain amplifier	O (3 ch. x 2 units)			
	Window comparator	O (3 ch. x 2 units)			
10-bit A/D converter (ADA)		O (12 ch.)		O (4 ch.)	—
CRC calculator (CRC)		O			
I/O ports	I/O pins	61	55	44	37
	Input pins	21	21	13	9
Package		LQFP2020 (0.65-mm pitch)	LQFP1414 (0.5-mm pitch)	LQFP1414 (0.65-mm pitch)	LQFP1010 (0.5-mm pitch) LQFP1414 (0.8mm pitch)

Note 1. O: Supported, —: Not supported
Note 2. * For the MTU and GPT, the number of pins will differ with the package. See the list of pins and pin functions for details. In addition, the CAN module is an optional function.

1.2 List of Products

Table 1.3 is a list of products, and Figure 1.1 shows how to read the product part no.

Table 1.3 List of Products

Group	Part No.	Package			Operating Frequency (Max.)	ROM Capacity	RAM Capacity	Data Flash	Operating Voltage		CAN
		Package Type	Pin Pitch	Package Code					VCC/ PLLVCC	AVCC/ AVCC0	
RX62T	R5F562TAADFH	LQFP2020-112	0.65 mm	PLQP0112JA-A	100 MHz	256 Kbytes	16 Kbytes	32K bytes	4.0 to 5.5 V	4.0 to 5.5 V	Supported
	R5F562TAADFP	LQFP1414-100	0.5 mm	PLQP0100KB-A							
	R5F562TAADFF	LQFP1414-80	0.65 mm	PLQP0080JA-A							
	R5F562TAADFM	LQFP1010-64	0.5 mm	PLQP0064KB-A							
	R5F562TAADFK	LQFP1414-64	0.8mm	PLQP0064GA-A							
	R5F562T7ADFH	LQFP2020-112	0.65 mm	PLQP0112JA-A		128 Kbytes	8 Kbytes	8K bytes			
	R5F562T7ADFP	LQFP1414-100	0.5 mm	PLQP0100KB-A							
	R5F562T7ADFF	LQFP1414-80	0.65 mm	PLQP0080JA-A							
	R5F562T7ADFM	LQFP1010-64	0.5 mm	PLQP0064KB-A							
	R5F562T7ADFK	LQFP1414-64	0.8mm	PLQP0064GA-A							
	R5F562T6ADFF	LQFP1414-80	0.65 mm	PLQP0080JA-A		64 Kbytes	8 Kbytes				
	R5F562T6ADFM	LQFP1010-64	0.5 mm	PLQP0064KB-A							
	R5F562T6ADFK	LQFP1414-64	0.8mm	PLQP0064GA-A							
	R5F562TABDFH	LQFP2020-112	0.65 mm	PLQP0112JA-A		256 Kbytes	16 Kbytes	32K bytes	2.7 to 3.6 V	3.0 to 3.6 V or 4.0 to 5.5 V	
	R5F562TABDFP	LQFP1414-100	0.5 mm	PLQP0100KB-A							
	R5F562TABDFF	LQFP1414-80	0.65 mm	PLQP0080JA-A							
	R5F562TABDFM	LQFP1010-64	0.5 mm	PLQP0064KB-A							
	R5F562TABDFK	LQFP1414-64	0.8mm	PLQP0064GA-A							
	R5F562T7BDFH	LQFP2020-112	0.65 mm	PLQP0112JA-A		128 Kbytes	8 Kbytes	8K bytes			
	R5F562T7BDFP	LQFP1414-100	0.5 mm	PLQP0100KB-A							
	R5F562T7BDFF	LQFP1414-80	0.65 mm	PLQP0080JA-A							
	R5F562T7BDFM	LQFP1010-64	0.5 mm	PLQP0064KB-A							
	R5F562T7BDFK	LQFP1414-64	0.8mm	PLQP0064GA-A							
	R5F562T6BDFF	LQFP1414-80	0.65 mm	PLQP0080JA-A		64 Kbytes	8 Kbytes				
	R5F562T6BDFM	LQFP1010-64	0.5 mm	PLQP0064KB-A							
	R5F562T6BDFK	LQFP1414-64	0.8mm	PLQP0064GA-A							
	R5F562TADDFH	LQFP2020-112	0.65 mm	PLQP0112JA-A		256 Kbytes	16 Kbytes	32K bytes	4.0 to 5.5 V	4.0 to 5.5 V	Not supported
	R5F562TADDFP	LQFP1414-100	0.5 mm	PLQP0100KB-A							
	R5F562TADDFF	LQFP1414-80	0.65 mm	PLQP0080JA-A							
	R5F562TADDFM	LQFP1010-64	0.5 mm	PLQP0064KB-A							
	R5F562TADDFK	LQFP1414-64	0.8mm	PLQP0064GA-A							
	R5F562T7DDFH	LQFP2020-112	0.65 mm	PLQP0112JA-A		128 Kbytes	8 Kbytes	8K bytes			
	R5F562T7DDFP	LQFP1414-100	0.5 mm	PLQP0100KB-A							
	R5F562T7DDFF	LQFP1414-80	0.65 mm	PLQP0080JA-A							
	R5F562T7DDFM	LQFP1010-64	0.5 mm	PLQP0064KB-A							
	R5F562T7DDFK	LQFP1414-64	0.8mm	PLQP0064GA-A							
	R5F562T6DFFF	LQFP1414-80	0.65 mm	PLQP0080JA-A		64 Kbytes	8 Kbytes				
	R5F562T6DDFM	LQFP1010-64	0.5 mm	PLQP0064KB-A							
	R5F562T6DDFK	LQFP1414-64	0.8mm	PLQP0064GA-A							
	R5F562TAEDFH	LQFP2020-112	0.65 mm	PLQP0112JA-A		256 Kbytes	16 Kbytes	32K bytes	2.7 to 3.6 V	3.0 to 3.6 V or 4.0 to 5.5 V	Not supported

Table 1.3 List of Products

Group	Part No.	Package			Operating Frequency (Max.)	ROM Capacity	RAM Capacity	Data Flash	Operating Voltage		CAN
		Package Type	Pin Pitch	Package Code					VCC/ PLLVCC	AVCC/ AVCC0	
RX62T	R5F562TAEDFP	LQFP1414-100	0.5 mm	PLQP0100KB-A	100 MHz	256 Kbytes	16 Kbytes	32K bytes	2.7 to 3.6 V	3.0 to 3.6 V or 4.0 to 5.5 V	Not supported
	R5F562TAEDFF	LQFP1414-80	0.65 mm	PLQP0080JA-A							
	R5F562TAEDFM	LQFP1010-64	0.5 mm	PLQP0064KB-A							
	R5F562TAEDFK	LQFP1414-64	0.8mm	PLQP0064GA-A							
	R5F562T7EDFH	LQFP2020-112	0.65 mm	PLQP0112JA-A		128 Kbytes	8 Kbytes	8K bytes			
	R5F562T7EDFP	LQFP1414-100	0.5 mm	PLQP0100KB-A							
	R5F562T7EDFF	LQFP1414-80	0.65 mm	PLQP0080JA-A							
	R5F562T7EDFM	LQFP1010-64	0.5 mm	PLQP0064KB-A							
	R5F562T7EDFK	LQFP1414-64	0.8mm	PLQP0064GA-A							
	R5F562T6EDFF	LQFP1414-80	0.65 mm	PLQP0080JA-A		64 Kbytes	8 Kbytes				
	R5F562T6EDFM	LQFP1010-64	0.5 mm	PLQP0064KB-A							
	R5F562T6EDFK	LQFP1414-64	0.8mm	PLQP0064GA-A							

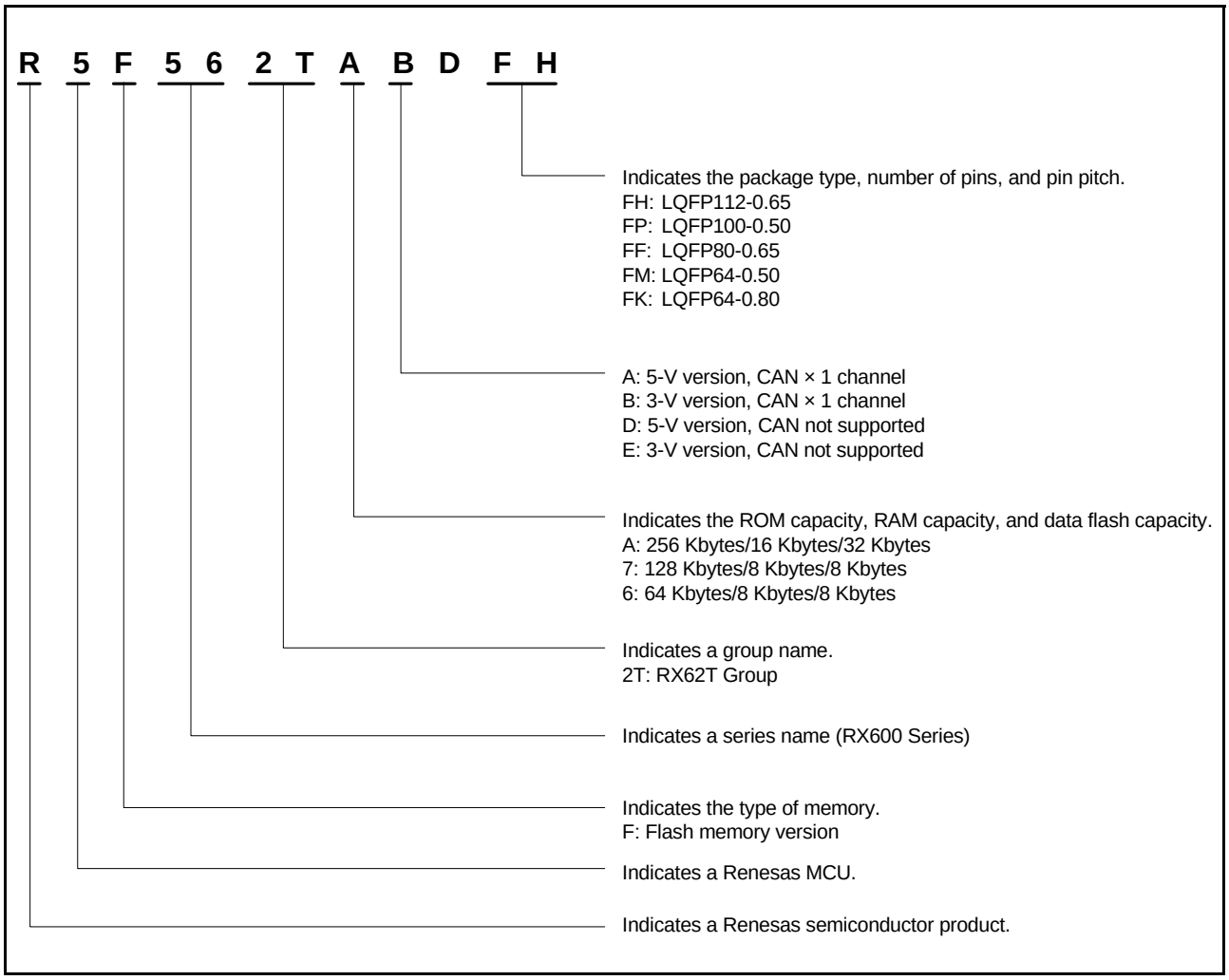
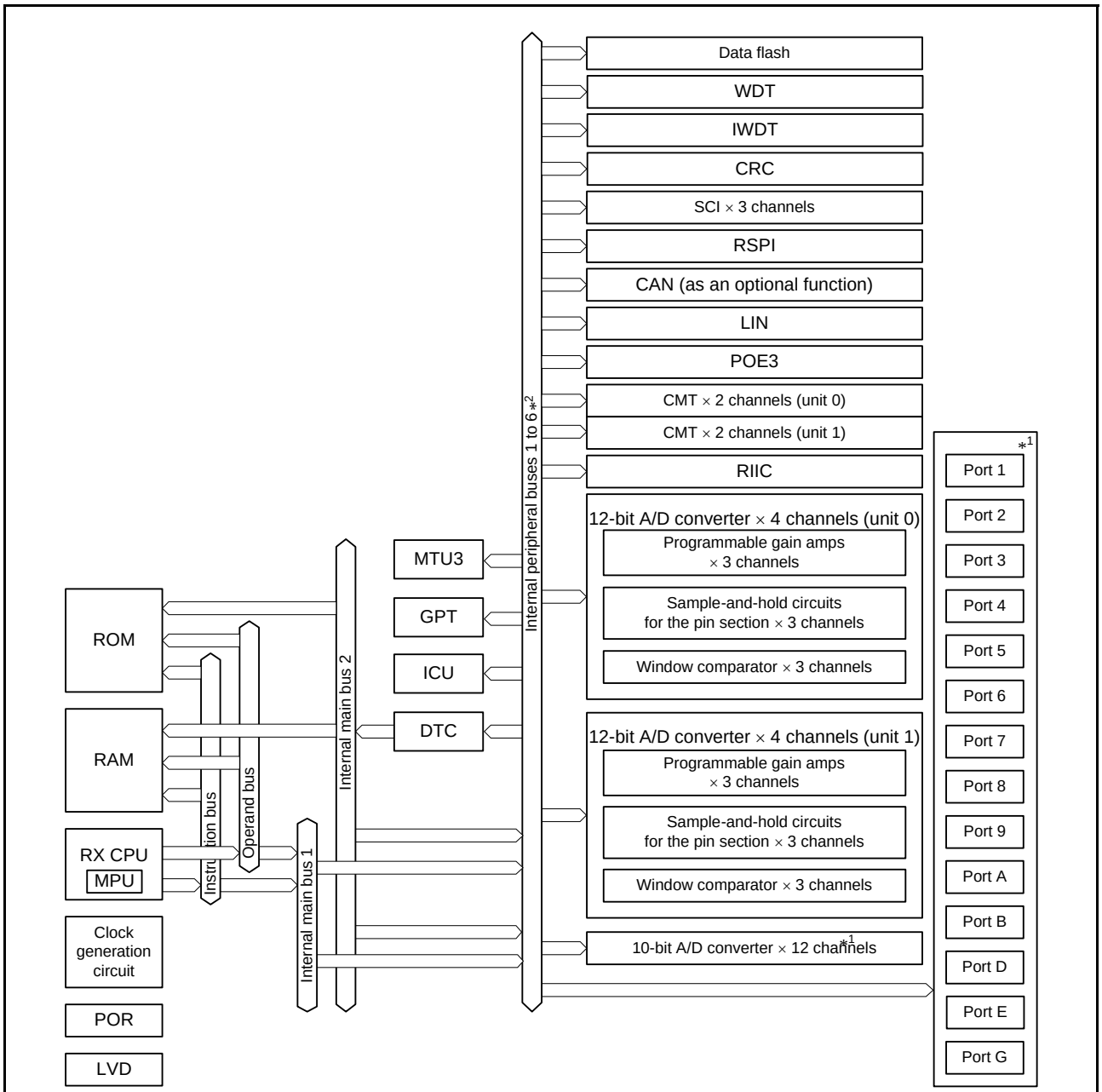


Figure 1.1 How to Read the Product Part No.

1.3 Block Diagram

Figure 1.2 shows a block diagram.



[Legend]

POR:	Power-on reset circuit	CAN:	CAN module
DTC:	Data transfer controller	LIN:	LIN module
MTU3:	Multi-function timer pulse unit 3	RSPI:	Renesas serial peripheral interface
POE3:	Port output enable 3	LVD:	Voltage detection circuit
GPT:	General PWM timer	ICU:	Interrupt controller
CMT:	Compare match timer	WDT:	Watchdog timer
SCI:	Serial communications interface	IWDT:	Independent watchdog timer
RIIC:	I^2C bus interface	CRC:	CRC (cyclic redundancy check) calculator
MPU:	Memory-Protection Unit		

Notes: 1. The installation of the 10-bit A/D converter and ports 1 to G is different depending on the package.
2. For details on the internal peripheral bus configuration, see section 12, Buses.

Figure 1.2 Block Diagram

1.4 Pin Assignments

Figure 1.3 to Figure 1.6 show the pins assignments. Table 1.4 to Table 1.7 show the list of pins and pin functions.

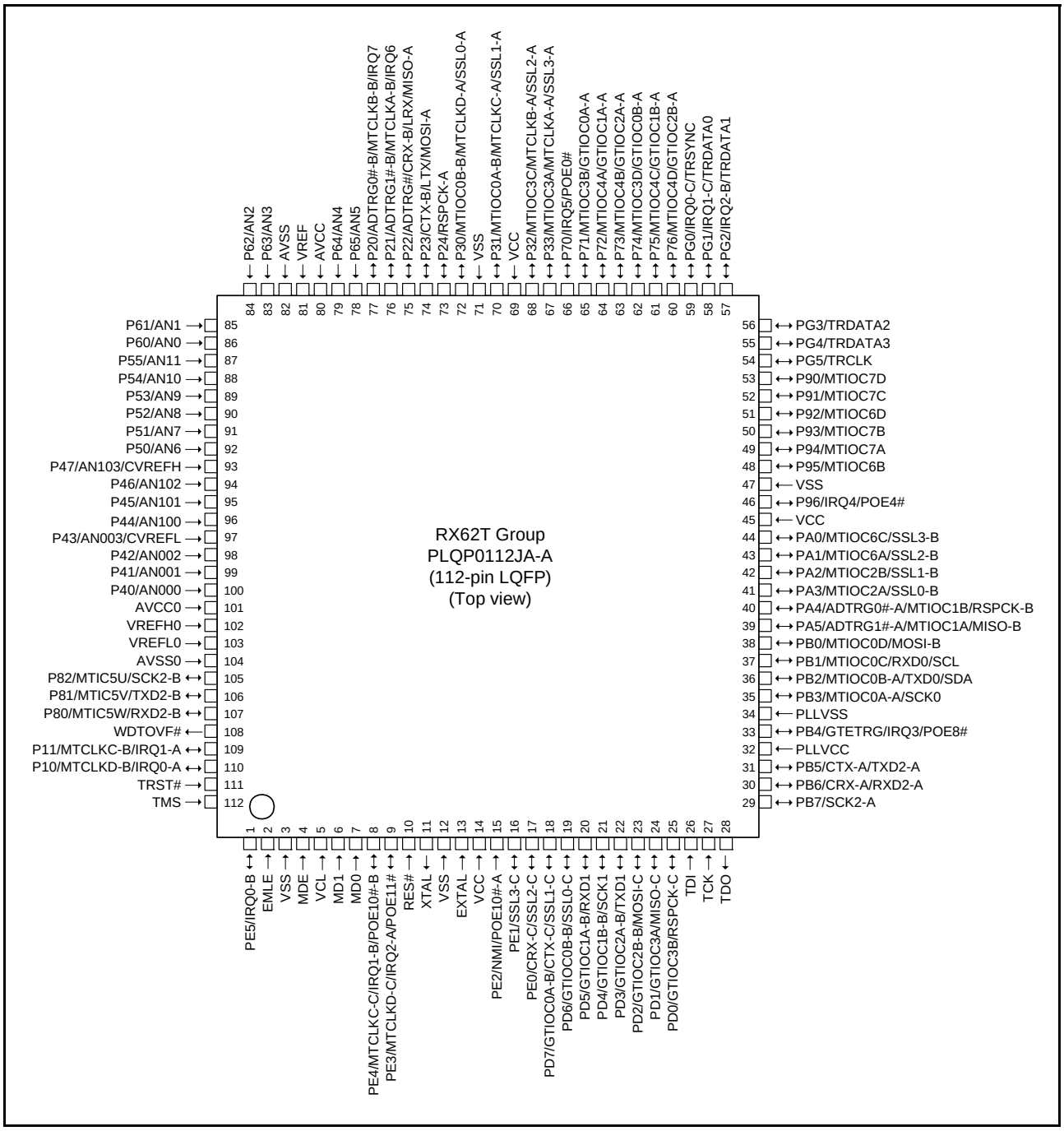


Figure 1.3 Pin Assignment of the 112-Pin LQFP

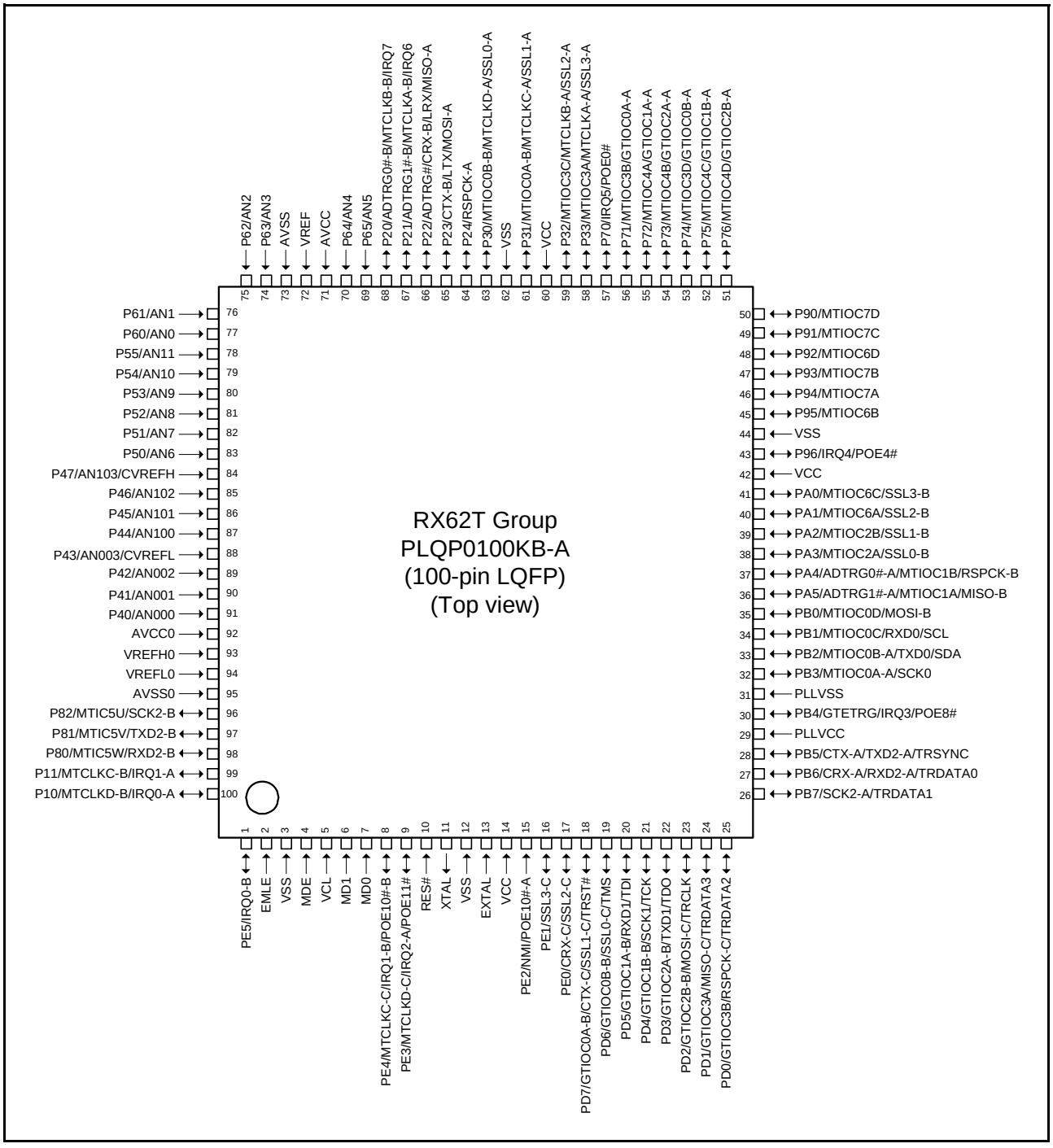


Figure 1.4 Pin Assignment of the 100-Pin LQFP

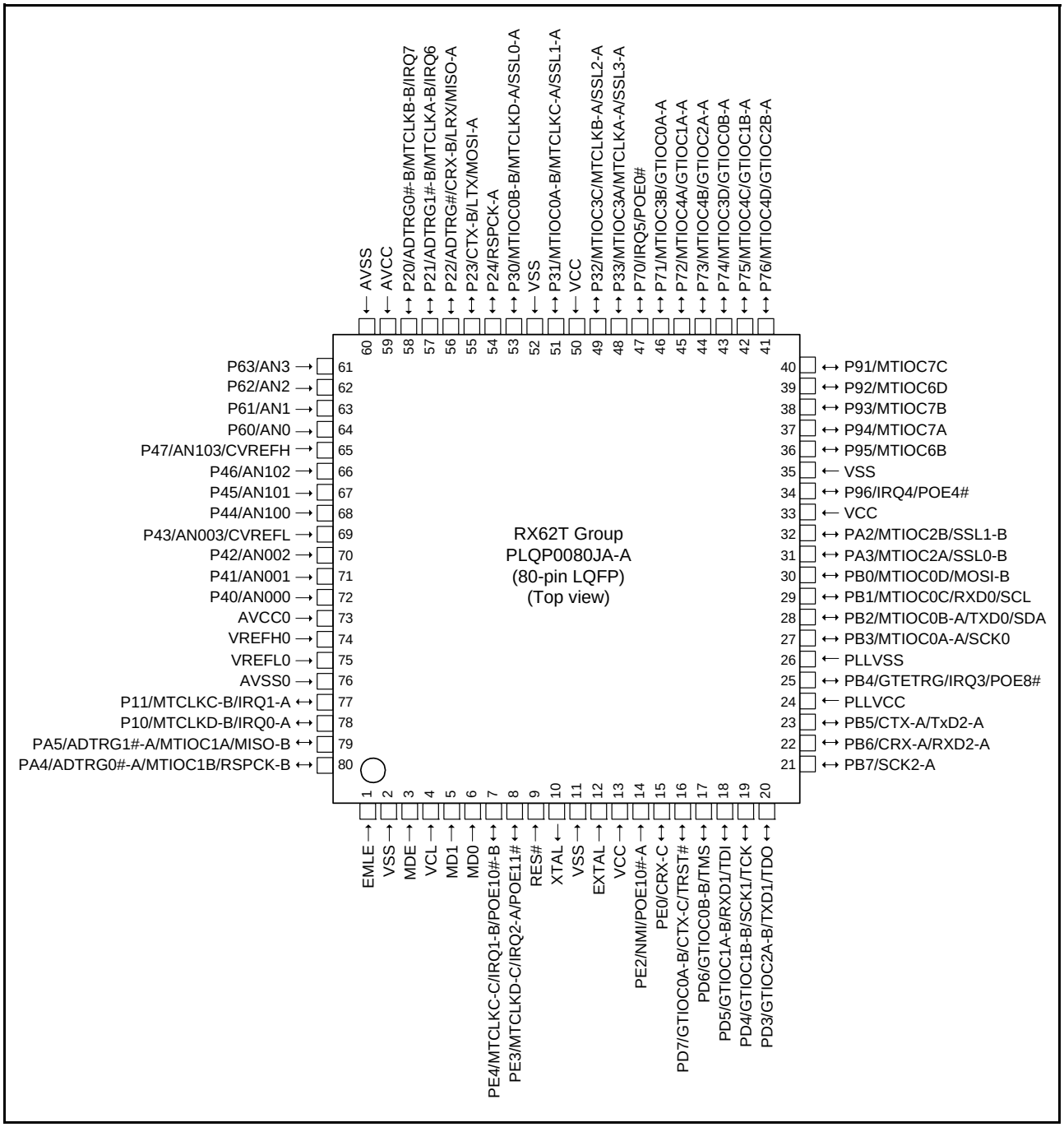


Figure 1.5 Pin Assignment of the 80-Pin LQFP

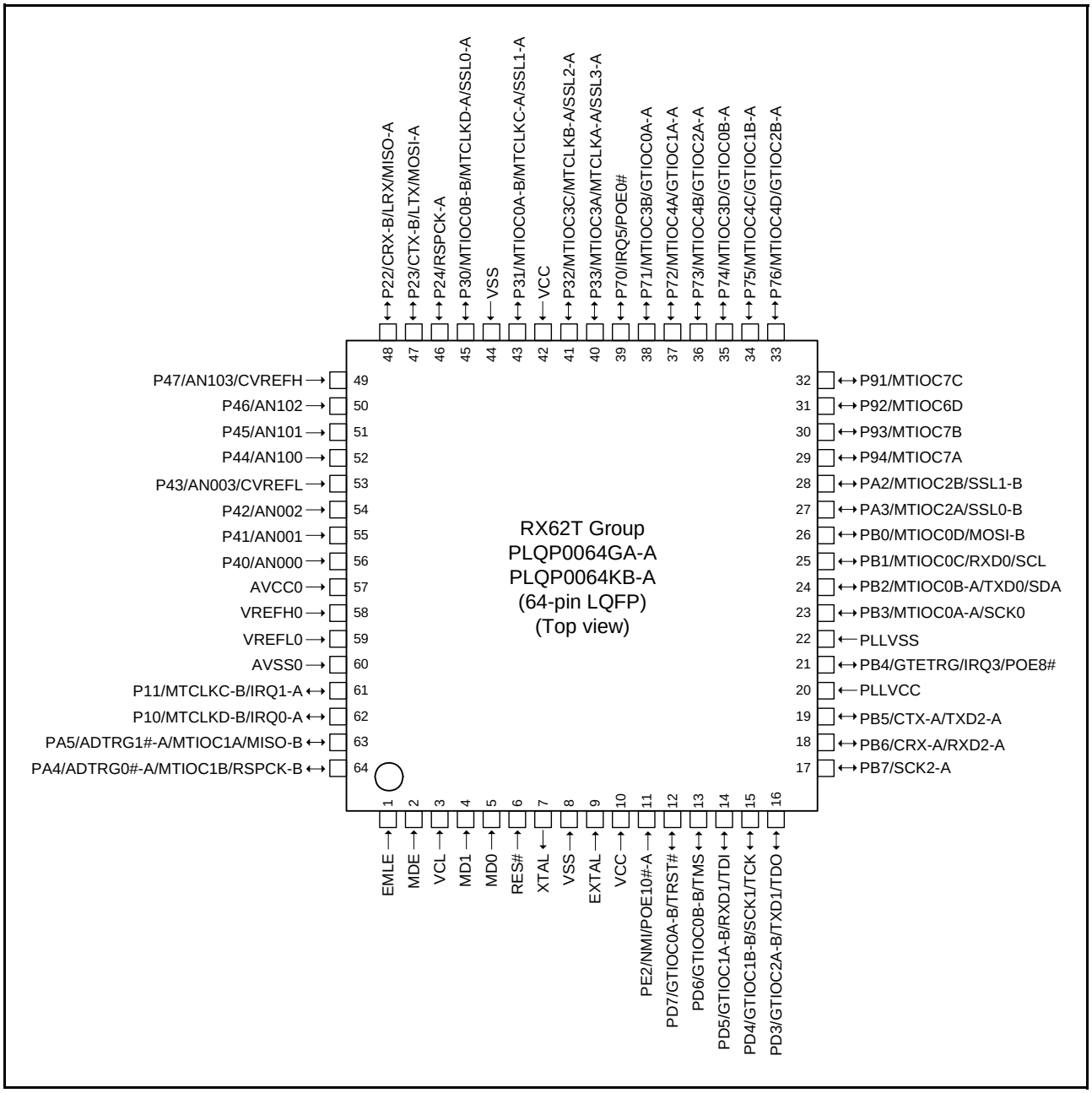


Figure 1.6 Pin Assignment of the 64-Pin LQFP

Table 1.4 List of Pins and Pin Functions (112-Pin LQFP) (1 / 3)

Pin No. (112-Pin LQFP)	Power Supply Clock System Control	I/O Port	Analog	Timer	Communi-cation	Interrupt	POE	Debugging
1		PE5				IRQ0-B		
2	EMLE							
3	VSS							
4	MDE							
5	VCL							
6	MD1							
7	MD0							
8		PE4		MTCLKC-C		IRQ1-B	POE10#-B	
9		PE3		MTCLKD-C		IRQ2-A	POE11#	
10	RES#							
11	XTAL							
12	VSS							
13	EXTAL							
14	VCC							
15		PE2				NMI	POE10#-A	
16		PE1			SSL3-C			
17		PE0			CRX-C/ SSL2-C			
18		PD7		GTIOC0A-B	CTX-C/ SSL1-C			
19		PD6		GTIOC0B-B	SSL0-C			
20		PD5		GTIOC1A-B	RXD1			
21		PD4		GTIOC1B-B	SCK1			
22		PD3		GTIOC2A-B	TXD1			
23		PD2		GTIOC2B-B	MOSI-C			
24		PD1		GTIOC3A	MISO-C			
25		PD0		GTIOC3B	RSPCK-C			
26								TDI
27								TCK
28								TDO
29		PB7			SCK2-A			
30		PB6			CRX-A/ RXD2-A			
31		PB5			CTX-A/ TXD2-A			
32	PLLVCC							
33		PB4		GTETRG		IRQ3	POE8#	
34	PLLVSS							
35		PB3		MTIOC0A-A	SCK0			
36		PB2		MTIOC0B-A	TXD0/SDA			
37		PB1		MTIOC0C	RXD0/SCL			
38		PB0		MTIOC0D	MOSI-B			
39		PA5	ADTRG1#-A	MTIOC1A	MISO-B			
40		PA4	ADTRG0#-A	MTIOC1B	RSPCK-B			
41		PA3		MTIOC2A	SSL0-B			
42		PA2		MTIOC2B	SSL1-B			
43		PA1		MTIOC6A	SSL2-B			

Table 1.4 List of Pins and Pin Functions (112-Pin LQFP) (2 / 3)

Pin No. (112-Pin LQFP)	Power Supply Clock System Control	I/O Port	Analog	Timer	Communi-cation	Interrupt	POE	Debugging
44		PA0		MTIOC6C	SSL3-B			
45	VCC							
46		P96				IRQ4	POE4#	
47	VSS							
48		P95		MTIOC6B				
49		P94		MTIOC7A				
50		P93		MTIOC7B				
51		P92		MTIOC6D				
52		P91		MTIOC7C				
53		P90		MTIOC7D				
54		PG5						TRCLK
55		PG4						TRDATA3
56		PG3						TRDATA2
57		PG2				IRQ2-B		TRDATA1
58		PG1				IRQ1-C		TRDATA0
59		PG0				IRQ0-C		TRSYNC
60		P76		MTIOC4D/ GTIOC2B-A				
61		P75		MTIOC4C/ GTIOC1B-A				
62		P74		MTIOC3D/ GTIOC0B-A				
63		P73		MTIOC4B/ GTIOC2A-A				
64		P72		MTIOC4A/ GTIOC1A-A				
65		P71		MTIOC3B/ GTIOC0A-A				
66		P70				IRQ5	POE0#	
67		P33		MTIOC3A/ MTCLKA-A	SSL3-A			
68		P32		MTIOC3C/ MTCLKB-A	SSL2-A			
69	VCC							
70		P31		MTIOC0A-B/ MTCLKC-A	SSL1-A			
71	VSS							
72		P30		MTIOC0B-B/ MTCLKD-A	SSL0-A			
73		P24			RSPCK-A			
74		P23			CTX-B/ LTX/ MOSI-A			
75		P22	ADTRG#		CRX-B/ LRX/ MISO-A			
76		P21	ADTRG1#-B	MTCLKA-B		IRQ6		
77		P20	ADTRG0#-B	MTCLKB-B		IRQ7		
78		P65	AN5					
79		P64	AN4					

Table 1.4 List of Pins and Pin Functions (112-Pin LQFP) (3 / 3)

Pin No. (112-Pin LQFP)	Power Supply Clock System Control	I/O Port	Analog	Timer	Communi-cation	Interrupt	POE	Debugging
80	AVCC							
81	VREF							
82	AVSS							
83		P63	AN3					
84		P62	AN2					
85		P61	AN1					
86		P60	AN0					
87		P55	AN11					
88		P54	AN10					
89		P53	AN9					
90		P52	AN8					
91		P51	AN7					
92		P50	AN6					
93		P47	AN103/ CVREFH					
94		P46	AN102					
95		P45	AN101					
96		P44	AN100					
97		P43	AN003/ CVREFL					
98		P42	AN002					
99		P41	AN001					
100		P40	AN000					
101	AVCC0							
102	VREFH0							
103	VREFL0							
104	AVSS0							
105		P82		MTIC5U	SCK2-B			
106		P81		MTIC5V	TXD2-B			
107		P80		MTIC5W	RXD2-B			
108				WDTOVF#				
109		P11		MTCLKC-B		IRQ1-A		
110		P10		MTCLKD-B		IRQ0-A		
111								TRST#
112								TMS

Table 1.5 List of Pins and Pin Functions (100-Pin LQFP) (1 / 3)

Pin No. (80-Pin LQFP)	Power Supply Clock System Control	I/O Port	Analog	Timer	Communi-cation	Interrupt	POE	Debugging
1		PE5				IRQ0-B		
2	EMLE							
3	VSS							
4	MDE							
5	VCL							
6	MD1							
7	MD0							
8		PE4		MTCLKC-C		IRQ1-B	POE10#-B	
9		PE3		MTCLKD-C		IRQ2-A	POE11#	
10	RES#							
11	XTAL							
12	VSS							
13	EXTAL							
14	VCC							
15		PE2				NMI	POE10#-A	
16		PE1			SSL3-C			
17		PE0			CRX-C/ SSL2-C			
18		PD7		GTIOC0A-B	CTX-C/ SSL1-C			TRST#
19		PD6		GTIOC0B-B	SSL0-C			TMS
20		PD5		GTIOC1A-B	RXD1			TDI
21		PD4		GTIOC1B-B	SCK1			TCK
22		PD3		GTIOC2A-B	TXD1			TDO
23		PD2		GTIOC2B-B	MOSI-C			TRCLK
24		PD1		GTIOC3A	MISO-C			TRDATA3
25		PD0		GTIOC3B	RSPCK-C			TRDATA2
26		PB7			SCK2-A			TRDATA1
27		PB6			CRX-A/ RXD2-A			TRDATA0
28		PB5			CTX-A/ TXD2-A			TRSYNC
29	PLLVCC							
30		PB4		GTETRG		IRQ3	POE8#	
31	PLLVSS							
32		PB3		MTIOC0A-A	SCK0			
33		PB2		MTIOC0B-A	TXD0/SDA			
34		PB1		MTIOC0C	RXD0/SCL			
35		PB0		MTIOC0D	MOSI-B			
36		PA5	ADTRG1#-A	MTIOC1A	MISO-B			
37		PA4	ADTRG0#-A	MTIOC1B	RSPCK-B			
38		PA3		MTIOC2A	SSL0-B			
39		PA2		MTIOC2B	SSL1-B			
40		PA1		MTIOC6A	SSL2-B			

Table 1.5 List of Pins and Pin Functions (100-Pin LQFP) (2 / 3)

Pin No. (80-Pin LQFP)	Power Supply Clock System Control	I/O Port	Analog	Timer	Communi-cation	Interrupt	POE	Debugging
41		PA0		MTIOC6C	SSL3-B			
42	VCC							
43		P96				IRQ4	POE4#	
44	VSS							
45		P95		MTIOC6B				
46		P94		MTIOC7A				
47		P93		MTIOC7B				
48		P92		MTIOC6D				
49		P91		MTIOC7C				
50		P90		MTIOC7D				
51		P76		MTIOC4D/ GTIOC2B-A				
52		P75		MTIOC4C/ GTIOC1B-A				
53		P74		MTIOC3D/ GTIOC0B-A				
54		P73		MTIOC4B/ GTIOC2A-A				
55		P72		MTIOC4A/ GTIOC1A-A				
56		P71		MTIOC3B/ GTIOC0A-A				
57		P70				IRQ5	POE0#	
58		P33		MTIOC3A/ MTCLKA-A	SSL3-A			
59		P32		MTIOC3C/ MTCLKB-A	SSL2-A			
60	VCC							
61		P31		MTIOC0A-B/ MTCLKC-A	SSL1-A			
62	VSS							
63		P30		MTIOC0B-B/ MTCLKD-A	SSL0-A			
64		P24			RSPCK-A			
65		P23			CTX-B/ LTX/ MOSI-A			
66		P22	ADTRG#		CRX-B/ LRX/ MISO-A			
67		P21	ADTRG1#-B	MTCLKA-B		IRQ6		
68		P20	ADTRG0#-B	MTCLKB-B		IRQ7		
69		P65	AN5					
70		P64	AN4					
71	AVCC							
72	VREF							
73	AVSS							
74		P63	AN3					
75		P62	AN2					
76		P61	AN1					

Table 1.5 List of Pins and Pin Functions (100-Pin LQFP) (3 / 3)

Pin No. (80-Pin LQFP)	Power Supply Clock System Control	I/O Port	Analog	Timer	Communi-cation	Interrupt	POE	Debugging
77		P60	AN0					
78		P55	AN11					
79		P54	AN10					
80		P53	AN9					
81		P52	AN8					
82		P51	AN7					
83		P50	AN6					
84		P47	AN103/ CVREFH					
85		P46	AN102					
86		P45	AN101					
87		P44	AN100					
88		P43	AN003/ CVREFL					
89		P42	AN002					
90		P41	AN001					
91		P40	AN000					
92	AVCC0							
93	VREFH0							
94	VREFL0							
95	AVSS0							
96		P82		MTIC5U	SCK2-B			
97		P81		MTIC5V	TXD2-B			
98		P80		MTIC5W	RXD2-B			
99		P11		MTCLKC-B		IRQ1-A		
100		P10		MTCLKD-B		IRQ0-A		

Table 1.6 List of Pins and Pin Functions (80-Pin LQFP) (1 / 3)

Pin No. (80-Pin LQFP)	Power Supply Clock System Control	I/O Port	Analog	Timer	Communi-cation	Interrupt	POE	Debugging
1	EMLE							
2	VSS							
3	MDE							
4	VCL							
5	MD1							
6	MD0							
7		PE4		MTCLKC-C		IRQ1-B	POE10#-B	
8		PE3		MTCLKD-C		IRQ2-A	POE11#	
9	RES#							
10	XTAL							
11	VSS							
12	EXTAL							
13	VCC							
14		PE2				NMI	POE10#-A	
15		PE0			CRX-C			
16		PD7		GTIOC0A-B	CTX-C			TRST#
17		PD6		GTIOC0B-B				TMS
18		PD5		GTIOC1A-B	RXD1			TDI
19		PD4		GTIOC1B-B	SCK1			TCK
20		PD3		GTIOC2A-B	TXD1			TDO
21		PB7			SCK2-A			
22		PB6			CRX-A/ RXD2-A			
23		PB5			CTX-A/ TXD2-A			
24	PLLVCC							
25		PB4		GTETRG		IRQ3	POE8#	
26	PLLVSS							
27		PB3		MTIOC0A-A	SCK0			
28		PB2		MTIOC0B-A	TXD0/SDA			
29		PB1		MTIOC0C	RXD0/SCL			
30		PB0		MTIOC0D	MOSI-B			
31		PA3		MTIOC2A	SSL0-B			
32		PA2		MTIOC2B	SSL1-B			
33	VCC							
34		P96				IRQ4	POE4#	
35	VSS							
36		P95		MTIOC6B				
37		P94		MTIOC7A				
38		P93		MTIOC7B				
39		P92		MTIOC6D				
40		P91		MTIOC7C				
41		P76		MTIOC4D/ GTIOC2B-A				

Table 1.6 List of Pins and Pin Functions (80-Pin LQFP) (2 / 3)

Pin No. (80-Pin LQFP)	Power Supply Clock System Control	I/O Port	Analog	Timer	Communi-cation	Interrupt	POE	Debugging
42		P75		MTIOC4C/ GTIOC1B-A				
43		P74		MTIOC3D/ GTIOC0B-A				
44		P73		MTIOC4B/ GTIOC2A-A				
45		P72		MTIOC4A/ GTIOC1A-A				
46		P71		MTIOC3B/ GTIOC0A-A				
47		P70				IRQ5	POE0#	
48		P33		MTIOC3A/ MTCLKA-A	SSL3-A			
49		P32		MTIOC3C/ MTCLKB-A	SSL2-A			
50	VCC							
51		P31		MTIOC0A-B/ MTCLKC-A	SSL1-A			
52	VSS							
53		P30		MTIOC0B-B/ MTCLKD-A	SSL0-A			
54		P24			RSPCK-A			
55		P23			CTX-B/ LTX/ MOSI-A			
56		P22	ADTRG#		CRX-B/ LRX/ MISO-A			
57		P21	ADTRG1#-B	MTCLKA-B		IRQ6		
58		P20	ADTRG0#-B	MTCLKB-B		IRQ7		
59	AVCC							
60	AVSS							
61		P63	AN3					
62		P62	AN2					
63		P61	AN1					
64		P60	AN0					
65		P47	AN103/ CVREFH					
66		P46	AN102					
67		P45	AN101					
68		P44	AN100					
69		P43	AN003/ CVREFL					
70		P42	AN002					
71		P41	AN001					
72		P40	AN000					
73	AVCC0							
74	VREFH0							
75	VREFL0							

Table 1.6 List of Pins and Pin Functions (80-Pin LQFP) (3 / 3)

Pin No. (80-Pin LQFP)	Power Supply Clock System Control	I/O Port	Analog	Timer	Communi-cation	Interrupt	POE	Debugging
76	AVSS0							
77		P11		MTCLKC-B		IRQ1-A		
78		P10		MTCLKD-B		IRQ0-A		
79		PA5	ADTRG1#-A	MTIOC1A	MISO-B			
80		PA4	ADTRG0#-A	MTIOC1B	RSPCK-B			

Table 1.7 List of Pins and Pin Functions (64-Pin LQFP) (1 / 2)

Pin No. (64-Pin LQFP)	Power Supply Clock System Control	I/O Port	Analog	Timer	Communi-cation	Interrupt	POE	Debuggi ng
1	EMLE							
2	MDE							
3	VCL							
4	MD1							
5	MD0							
6	RES#							
7	XTAL							
8	VSS							
9	EXTAL							
10	VCC							
11		PE2				NMI	POE10#-A	
12		PD7		GTIOC0A-B				TRST#
13		PD6		GTIOC0B-B				TMS
14		PD5		GTIOC1A-B	RXD1			TDI
15		PD4		GTIOC1B-B	SCK1			TCK
16		PD3		GTIOC2A-B	TXD1			TDO
17		PB7			SCK2-A			
18		PB6			CRX-A/ RXD2-A			
19		PB5			CTX-A/ TXD2-A			
20	PLLVCC							
21		PB4		GTETRG		IRQ3	POE8#	
22	PLLVSS							
23		PB3		MTIOC0A-A	SCK0			
24		PB2		MTIOC0B-A	TXD0/SDA			
25		PB1		MTIOC0C	RXD0/SCL			
26		PB0		MTIOC0D	MOSI-B			
27		PA3		MTIOC2A	SSL0-B			
28		PA2		MTIOC2B	SSL1-B			
29		P94		MTIOC7A				
30		P93		MTIOC7B				
31		P92		MTIOC6D				
32		P91		MTIOC7C				
33		P76		MTIOC4D/ GTIOC2B-A				
34		P75		MTIOC4C/ GTIOC1B-A				
35		P74		MTIOC3D/ GTIOC0B-A				
36		P73		MTIOC4B/ GTIOC2A-A				
37		P72		MTIOC4A/ GTIOC1A-A				
38		P71		MTIOC3B/ GTIOC0A-A				
39		P70				IRQ5	POE0#	

Table 1.7 List of Pins and Pin Functions (64-Pin LQFP) (2 / 2)

Pin No. (64-Pin LQFP)	Power Supply Clock System Control	I/O Port	Analog	Timer	Communi-cation	Interrupt	POE	Debuggi ng
40		P33		MTIOC3A/ MTCLKA-A	SSL3-A			
41		P32		MTIOC3C/ MTCLKB-A	SSL2-A			
42	VCC							
43		P31		MTIOC0A-B/ MTCLKC-A	SSL1-A			
44	VSS							
45		P30		MTIOC0B-B/ MTCLKD-A	SSL0-A			
46		P24			RSPCK-A			
47		P23			CTX-B/ LTX/ MOSI-A			
48		P22			CRX-B/ LRX/ MISO-A			
49		P47	AN103/ CVREFH					
50		P46	AN102					
51		P45	AN101					
52		P44	AN100					
53		P43	AN003/ CVREFL					
54		P42	AN002					
55		P41	AN001					
56		P40	AN000					
57	AVCC0							
58	VREFH0							
59	VREFL0							
60	AVSS0							
61		P11		MTCLKC-B		IRQ1-A		
62		P10		MTCLKD-B		IRQ0-A		
63		PA5	ADTRG1#-A	MTIOC1A	MISO-B			
64		PA4	ADTRG0#-A	MTIOC1B	RSPCK-B			

1.5 Pin Functions

Table 1.8 lists the pin functions.

Table 1.8 Pin Functions (1 / 4)

Classifications	Pin Name	I/O	Description
Power supply	VCC	Input	Power supply pin. Connect it to the system power supply.
	VCL	Input	Connect this pin to VSS via a 0.1-μF capacitor. The capacitor should be placed close to the pin.
	VSS	Input	Ground pin. Connect it to the system power supply (0 V).
	PLLVCC	Input	Power supply pin for the PLL circuit. Connect it to the system power supply.
	PLLVSS	Input	Ground pin for the PLL circuit.
Clock	XTAL	Output	Pins for a crystal resonator. An external clock signal can be input through the EXTAL pin.
	EXTAL	Input	
Operating mode control	MD0 MD1 MDE	Input	Pins for setting the operating mode. The signal levels on these pins must not be changed during operation.
System control	RES#	Input	Reset signal input pin. This LSI enters the reset state when this signal goes low.
	EMLE	Input	Input pin for the on-chip emulator enable signal. When the on-chip emulator is used, this pin should be driven high. When not used, it should be driven low.
On-chip emulator	TRST#	Input	On-chip emulator pins. When the EMLE pin is driven high, these pins are dedicated for the on-chip emulator.
	TMS	Input	
	TDI	Input	
	TCK	Input	
	TDO	Output	
	TRCLK	Output	This pin outputs the clock for synchronization with the trace data. Not included in the 80-/64-pin versions.
	TRSYNC	Output	This pin indicates that output from the TRDATA0 to TRDATA3 pins is valid. Not included in the 80-/64-pin versions.
	TRDATA0 to TRDATA3	Output	These pins output the trace information. Not included in the 80-/64-pin versions.
Interrupt (ICU)	NMI	Input	Non-maskable interrupt request signal.
	IRQ0-A/IRQ0-B/IRQ0-C IRQ1-A/IRQ1-B/IRQ1-C IRQ2-A/IRQ2-B IRQ3 to IRQ7	Input	Interrupt request signals. The IRQ0-C/IRQ1-C/IRQ2-B pin is not included in the 100-pin version. The IRQ0-B/IRQ0-C/IRQ1-C/IRQ2-B pin is not included in the 80-pin version. The IRQ0-B/IRQ0-C/IRQ1-B/IRQ1-/IRQ2-A/IRQ2-B/IRQ4/IRQ6/IRQ7 pin is not included in the 64-pin version.

Table 1.8 Pin Functions (2 / 4)

Classifications	Pin Name	I/O	Description
Multi-function timer pulse unit 3 (MTU3)	MTIOC0A-A/MTIOC0A-B MTIOC0B-A/MTIOC0B-B MTIOC0C, MTIOC0D	I/O	The MTU0.TGRA to MTU0.TGRD input capture input/output compare output/PWM output pins.
	MTIOC1A, MTIOC1B	I/O	The MTU1.TGRA and MTU1.TGRB input capture input/output compare output/PWM output pins.
	MTIOC2A, MTIOC2B	I/O	The MTU2.TGRA and MTU2.TGRB input capture input/output compare output/PWM output pins.
	MTIOC3A, MTIOC3B MTIOC3C, MTIOC3D	I/O	The MTU3.TGRA and MTU3.TGRD input capture input/output compare output/PWM output pins. Pins MTIOC3B and MTIOC3D can be used for large-current output.
	MTIOC4A, MTIOC4B MTIOC4C, MTIOC4D	I/O	The MTU4.TGRA and MTU4.TGRD input capture input/output compare output/PWM output pins. These pins can be used for large-current output.
	MTIC5U, MTIC5V, MTIC5W	Input	The MTU5.TGRU, MTU5.TGRV, and MTU5.TGRW input capture input/dead time compensation input pins. Not included in the 80-/64-pin versions.
	MTIOC6A, MTIOC6B MTIOC6C, MTIOC6D	I/O	The MTU6.TGRA to MTU6.TGRD input capture input/output compare output/PWM output pins. Pins MTIOC6B and MTIOC6D can be used for large-current output. The MTIOC6A/MTIOC6C pin is not included in the 80-pin version. The MTIOC6A/MTIOC6B/MTIOC6C pin is not included in the 64-pin version.
	MTIOC7A, MTIOC7B MTIOC7C, MTIOC7D	I/O	The MTU7.TGRA to MTU7.TGRD input capture input/output compare output/PWM output pins. These pins can be used for large-current output. The MTIOC7D pin is not included in the 80-/64-pin versions.
	MTCLKA-A/MTCLKA-B MTCLKB-A/MTCLKB-B MTCLKC-A/MTCLKC-B/ MTCLKC-C MTCLKD-A/MTCLKD-B/ MTCLKD-C	Input	Input pins for external clock signals. The MTCLKA-B/MTCLKB-B/ MTCLKC-C/MTCLKD-C pin is not included in the 64-pin version.
General PWM timer (GPT)	GTIOC0A-A/GTIOC0A-B GTIOC0B-A/GTIOC0B-B	I/O	The GPT0.GTCCRA and GPT0.GTCCRB CCRB input capture input/output compare output/PWM output pins. Pins GTIOC0A-A and GTIOC0B-A can be used for large-current output.
	GTIOC1A-A/GTIOC1A-B GTIOC1B-A/GTIOC1B-B	I/O	The GPT1.GTCCRA and GPT1.GTCCRB input capture input/ output compare output/PWM output pins. Pins GTIOC1A-A and GTIOC1B-A can be used for large-current output.
	GTIOC2A-A/GTIOC2A-B GTIOC2B-A/GTIOC2B-B	I/O	The GPT2.GTCCRA and GPT2.GTCCRB input capture input/ output compare output/PWM output pins. Pins GTIOC2A-A and GTIOC2B-A can be used for large-current output. The GTIOC2B-B pin is not included in the 80-pin version.
	GTIOC3A, GTIOC3B	I/O	The GPT3.GTCCRA and GPT3.GTCCRB input capture input/ output compare output/PWM output pins. Not included in the 80-/64-pin versions.
	GTETRG	Input	External trigger input pin for the GPT
Port output enable 3 (POE3)	POE0#, POE4#, POE8# POE10#-A/POE10#-B POE11#	Input	Input pins for request signals to place the MTU3 and GPT large-current pins in the high impedance state. The POE4#/ POE10#-B/POE11# pin is not included in the 64-pin version.
Watchdog timer (WDT)	WDTOVF#	Output	Output pin for the counter-overflow signal in watchdog-timer mode. Not included in the 100-/80-/64-pin versions.

Table 1.8 Pin Functions (3 / 4)

Classifications	Pin Name	I/O	Description
Serial communications interface (SCIb)	TXD0, TXD1, TXD2-A/TXD2-B	Output	Output pins for data transmission. The TXD2-B pin is not included in the 80-/64-pin versions.
	RXD0, RXD1, RXD2-A/ RXD2-B	Input	Input pins for data reception. The RXD2-B pin is not included in the 80-/64-pin versions.
	SCK0, SCK1, SCK2-A/ SCK2-B	I/O	Input/output pins for clock signals. The SCK2-B pin is not included in the 80-/64-pin versions.
I^2C bus interface (RIIC)	SCL	I/O	Input/output pin for I^2C bus interface clocks. Bus can be directly driven by the NMOS open drain output.
	SDA	I/O	Input/output pin for I^2C bus interface data. Bus can be directly driven by the NMOS open drain output.
CAN module (CAN) (as an optional function)	CRX-A/CRX-B/CRX-C	Input	Input pin for the CAN. The CRX-C pin is not included in the 64-pin version.
	CTX-A/CTX-B/CTX-C	Output	Output pin for the CAN. The CTX-C pin is not included in the 64-pin version.
LIN module (LIN)	LRX	Input	Input pin for the LIN.
	LTX	Output	Output pin for the LIN.
Serial peripheral interface (RSPI)	RSPCK-A/RSPCK-B/ RSPCK-C	I/O	Clock input/output pin for the RSPI. The RSPCK-C pin is not included in the 80-/64-pin versions.
	MOSI-A/MOSI-B/MOSI-C	I/O	Inputs or outputs data output from the master for the RSPI. The MOSI-C pin is not included in the 80-/64-pin versions.
	MISO-A/MISO-B/MISO-C	I/O	Inputs or outputs data output from the slave for the RSPI. The MISO-C pin is not included in the 80-/64-pin versions.
	SSL0-A/SSL0-B/SSL0-C	I/O	Select the slave for the RSPI. The SSL0-C/SSL1-C/SSL2-C/ SSL3-C pin is not included in the 80-/64-pin versions.
	SSL1-A/SSL1-B/SSL1-C SSL2-A/SSL2-B/SSL2-C SSL3-A/SSL3-B/SSL3-C	Output	
A/D converter	AN000 to AN003 AN100 to AN103	Input	Input pins for the analog signals to be processed by the 12-bit A/D converter.
	AN0 to AN11	Input	Input pins for the analog signals to be processed by the 10-bit A/D converter. The AN4 to AN11 pins are not included in the 80-pin version. Not included in the 64-pin version.
	ADTRG0#-A/ADTRG0#-B ADTRG1#-A/ADTRG1#-B ADTRG#	Input	Input pins for the external trigger signals that start the A/D conversion. The ADTRG0#-B/ADTRG1#-B/ADTRG# pin is not included in the 64-pin version.
	CVREFH	Input	Input pin for the high-level reference voltage to the comparator
	CVREFL	Input	Input pin for the low-level reference voltage to the comparator
Analog power supply	AVCC0	Input	Analog power supply pin for the 12-bit A/D converter. When the A/D converter is not in use, connect this pin to the system power supply.
	AVSS0	Input	Ground pin for the 12-bit A/D converter. Connect this pin to the system power supply (0 V).
	VREFH0	Input	Reference power supply pin for the 12-bit A/D converter. When the 12-bit A/D converter is not in use, connect this pin to the system power supply.
	VREFL0	Input	Ground pin of the reference power supply pin for the 12-bit A/D converter. When the 12-bit A/D converter is not in use, connect this pin to the system power supply (0 V).
	AVCC	Input	Analog power supply pin for the 10-bit A/D converter. When the A/D converter is not in use, connect this pin to the system power supply. Not included in the 64-pin version.
	AVSS	Input	Ground pin for the 10-bit A/D converter. Connect this pin to the system power supply (0 V). Not included in the 64-pin version.
	VREF	Input	Reference power supply pin for the 10-bit A/D converter. When the 10-bit A/D converter is not in use, connect this pin to the system power supply. Not included in the 80-/64-pin versions.

Table 1.8 Pin Functions (4 / 4)

Classifications	Pin Name	I/O	Description
I/O ports	P10, P11	I/O	2-bit input/output pins.
	P20 to P24	I/O	5-bit input/output pins. The P20/P21 pin is not included in the 64-pin version.
	P30 to P33	I/O	4-bit input/output pins.
	P40 to P47	Input	8-bit input pins.
	P50 to P55	Input	6-bit input pins. Not included in the 80-/64-pin versions.
	P60 to P65	Input	6-bit input pins. The P64/P6 pin is not included in the 80-pin version. Not included in the 64-pin version.
	P70 to P76	I/O	7-bit input/output pins.
	P80 to P82	I/O	3-bit input/output pins. Not included in the 80-/64-pin versions.
	P90 to P96	I/O	7-bit input/output pins. The P90 pin is not included in the 80-pin version. The P90/P95/P96 pin is not included in the 64-pin version.
	PA0 to PA5	I/O	6-bit input/output pins. The PA0/PA1 pin is not included in the 80-/64-pin versions.
	PB0 to PB7	I/O	8-bit input/output pins.
	PD0 to PD7	I/O	8-bit input/output pins. The PD0/PD1/PD2 pin is not included in the 80-/64-pin versions.
	PE0, PE1, PE3 to PE5	I/O	5-bit input/output pins. The PE1/PE5 pin is not included in the 80-pin version. Not included in the 64-pin version.
	PE2	Input	1-bit input pin.
	PG0 to PG5	I/O	6-bit input/output pins. Not included in the 100-/80-/64-pin versions.

Note: • Which pins are and are not incorporated depends on the package.
For details, see the list of pins and pin functions in Table 1.4 to Table 1.7.

2. CPU

The RX62T Group is an MCU with the high-speed, high-performance RX CPU as its core.
A variable-length instruction format has been adopted for the RX CPU. Allocating the more frequently used instructions to the shorter instruction lengths facilitates the development of efficient programs that take up less memory.
The CPU has 73 basic instructions and 8 floating-point operation instructions, and 9 DSP instructions, for a total of 90 instructions. It has 10 addressing modes and caters to register–register operations, register–memory operations, immediate–register operations, immediate–memory operations, memory–memory transfer, and bitwise operations. High-speed operation was realized by achieving execution in a single cycle not only for register–register operations, but also for other types of multiple instructions. The CPU includes an internal multiplier and an internal divider for high-speed multiplication and division.
The RX CPU has a five-stage pipeline for processing instructions. The stages are instruction fetching, instruction decoding, execution, memory access, and write-back. In cases where pipeline processing is drawn-out by memory access, subsequent operations may in fact be executed earlier. By adopting "out-of-order completion" of this kind, the execution of instructions is controlled to optimize numbers of clock cycles.

2.1 Features

- High instruction execution rate: One instruction in one clock cycle
- Address space: 4-Gbyte linear
- Register set of the CPU
  General purpose: Sixteen 32-bit registers
  Control: Nine 32-bit registers
  Accumulator: One 64-bit register
- Basic instructions: 73 (arithmetic/logic instructions, data-transfer instructions, branch instructions, bit-manipulation instructions, string-manipulation instructions, and system-manipulation instructions)
  Relative branch instructions to suit branch distances
  Variable-length instruction format (lengths from one to eight bytes)
  Short formats for frequently used instructions
- Floating-point operation instructions: 8
- DSP instructions: 9
  Supports 16-bit x 16-bit multiplication and multiply-and-accumulate operations.
  Rounds the data in the accumulator.
- Addressing modes: 10
- Five-stage pipeline
  Adoption of out-of-order completion
- Processor modes
  A supervisor mode and a user mode are supported.
- Floating-point operation unit
  Supports single-precision (32-bit) floating point
  Supports data types and exceptions in conformance with the IEEE754 standard
- Memory protection unit
- Data arrangement
  Selectable as little endian or big endian

2.2 Register Set of the CPU

The RX CPU has sixteen general-purpose registers, nine control registers, and one accumulator used for DSP instructions.

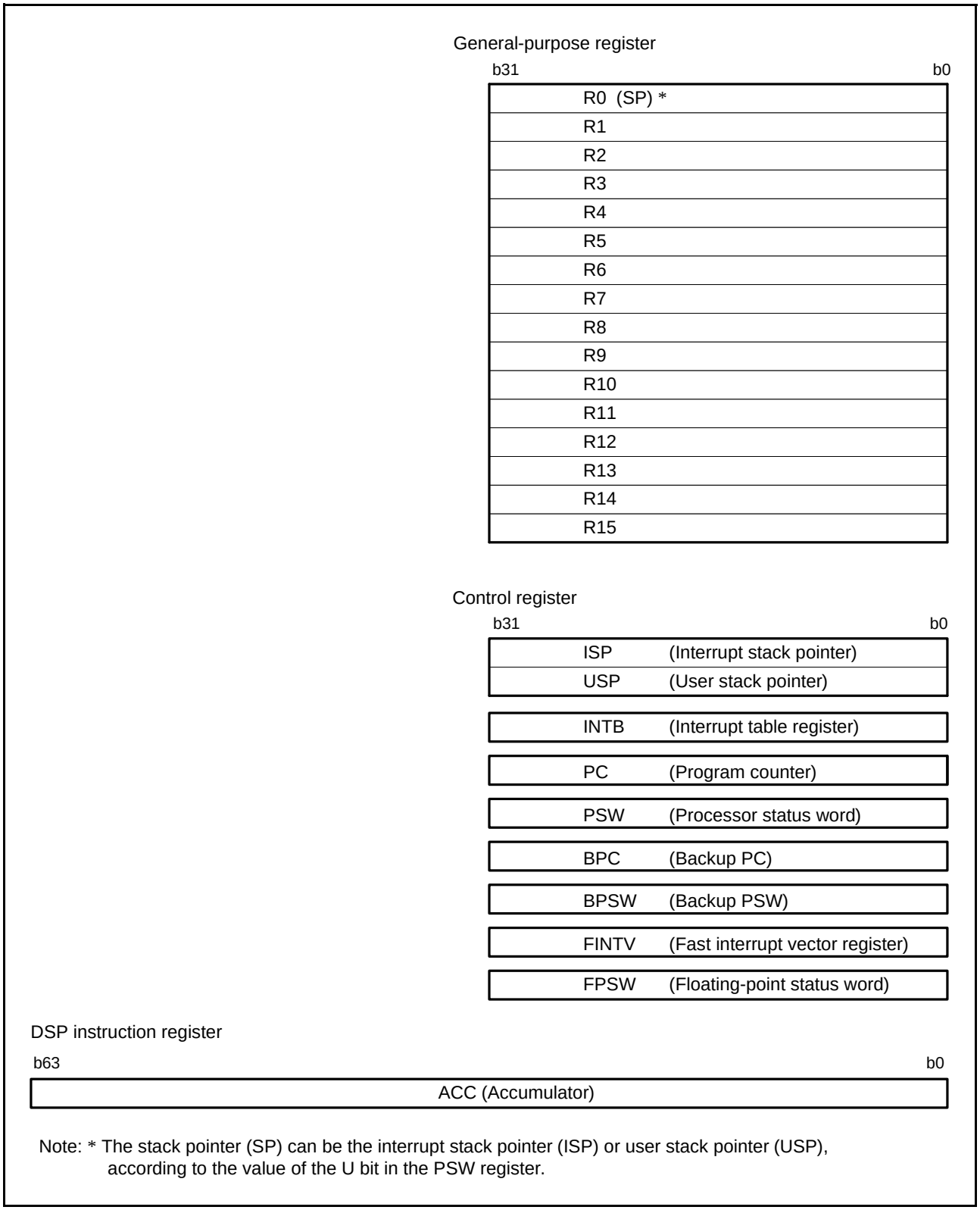


Figure 2.1 Register Set of the CPU

2.2.1 General-Purpose Registers (R0 to R15)

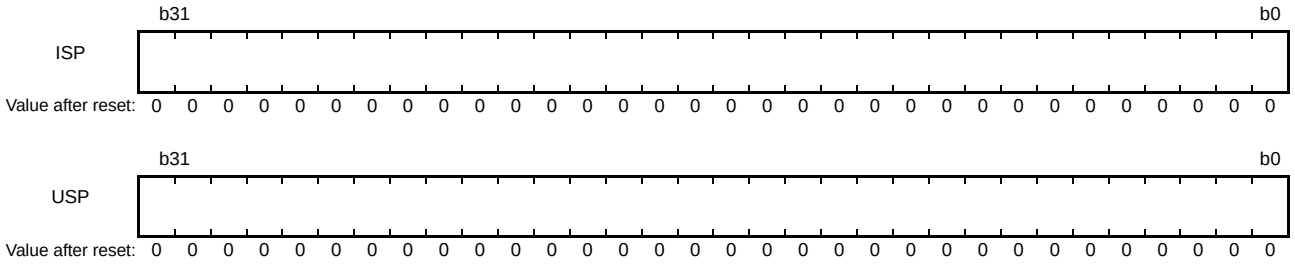
This CPU has sixteen general-purpose registers (R0 to R15). R1 to R15 can be used as data registers or address registers. R0, a general-purpose register, also functions as the stack pointer (SP). The stack pointer is switched to operate as the interrupt stack pointer (ISP) or user stack pointer (USP) by the value of the stack pointer select bit (U) in the processor status word (PSW).

2.2.2 Control Registers

This CPU has the following nine control registers.

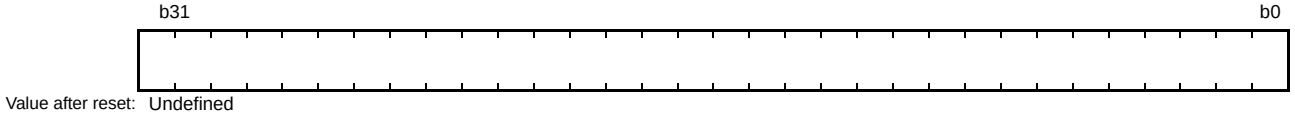
- Interrupt stack pointer (ISP)
- User stack pointer (USP)
- Interrupt table register (INTB)
- Program counter (PC)
- Processor status word (PSW)
- Backup PC (BPC)
- Backup PSW (BPSW)
- Fast interrupt vector register (FINTV)
- Floating-point status word (FPSW)

2.2.2.1 Interrupt Stack Pointer (ISP)/User Stack Pointer (USP)



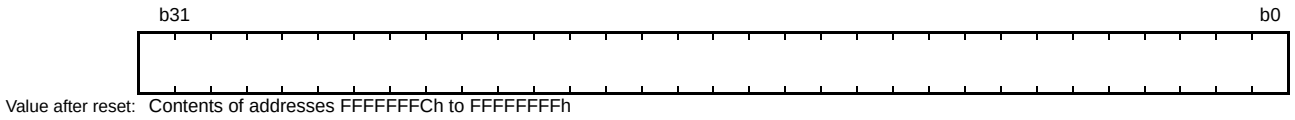
The stack pointer (SP) can be either of two types, the interrupt stack pointer (ISP) or the user stack pointer (USP). Whether the stack pointer operates as the ISP or USP depends on the value of the stack pointer select bit (U) in the processor status word (PSW).
Set the ISP or USP to a multiple of four, as this reduces the numbers of cycles required to execute interrupt sequences and instructions entailing stack manipulation.

2.2.2.2 Interrupt Table Register (INTB)



The interrupt table register (INTB) specifies the address where the relocatable vector table starts.
Set INTB to a multiple of four.

2.2.2.3 Program Counter (PC)



The program counter (PC) indicates the address of the instruction being executed.

2.2.2.4 Processor Status Word (PSW)

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
	—	—	—	—	IPL[3:0]				—	—	—	PM	—	—	U	I
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	—	—	—	—	O	S	Z	C
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	C	Carry Flag	0: No carry has occurred. 1: A carry has occurred.	R/W
b1	Z	Zero Flag	0: Result is non-zero. 1: Result is 0.	R/W
b2	S	Sign Flag	0: Result is a positive value or 0. 1: Result is a negative value.	R/W
b3	O	Overflow Flag	0: No overflow has occurred. 1: An overflow has occurred.	R/W
b15 to b4	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W
b16	I*1	Interrupt Enable	0: Interrupt disabled. 1: Interrupt enabled.	R/W
b17	U*1	Stack Pointer Select	0: Interrupt stack pointer (ISP) is selected. 1: User stack pointer (USP) is selected.	R/W
b19, b18	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W
b20	PM*1*2*3	Processor Mode Select	0: Supervisor mode is selected. 1: User mode is selected.	R/W
b23 to b21	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W
b27 to b24	IPL[3:0]*1	Processor Interrupt Priority Level	b27b24 0 0 0 0: Priority level 0 (lowest) 0 0 0 1: Priority level 1 0 0 1 0: Priority level 2 0 0 1 1: Priority level 3 0 1 0 0: Priority level 4 0 1 0 1: Priority level 5 0 1 1 0: Priority level 6 0 1 1 1: Priority level 7 1 0 0 0: Priority level 8 1 0 0 1: Priority level 9 1 0 1 0: Priority level 10 1 0 1 1: Priority level 11 1 1 0 0: Priority level 12 1 1 0 1: Priority level 13 1 1 1 0: Priority level 14 1 1 1 1: Priority level 15 (highest)	R/W
b31 to b28	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W

Note 1. In user mode, writing to the IPL[3:0], PM, U, and I bits by an MVTC or a POPC instruction is ignored. Writing to the IPL[3:0] bits by an MVTIPL instruction generates a privileged instruction exception.
Note 2. In supervisor mode, writing to the PM bit by an MVTC or a POPC instruction is ignored, but writing to the other bits is possible.
Note 3. Switching from supervisor mode to user mode requires execution of an RTE instruction after having set the PM bit in PSW saved on the stack to 1 or executing an RTFI instruction after having set the PM bit in BPSW to 1.

The processor status word (PSW) indicates results of instruction execution or the state of the CPU.

C Flag (Carry Flag)

This flag indicates whether a carry, borrow, or shift-out has occurred as the result of an operation.

Z Flag (Zero Flag)

This flag indicates that the result of an operation was 0.

S Flag (Sign Flag)

This flag indicates that the result of an operation was negative.

O Flag (Overflow Flag)

This flag indicates that an overflow occurred during an operation.

I Bit (Interrupt Enable)

This bit enables interrupt requests. When an exception is accepted, the value of this bit becomes 0.

U Bit (Stack Pointer Select)

This bit specifies the stack pointer as either the ISP or USP. When an exception request is accepted, this bit is set to 0. When the processor mode is switched from supervisor mode to user mode, this bit is set to 1.

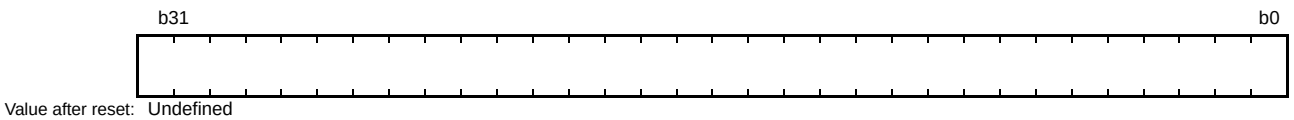
PM Bit (Processor Mode Select)

This bit specifies the processor mode. When an exception is accepted, the value of this bit becomes 0.

IPL[3:0] Bits (Processor Interrupt Priority Level)

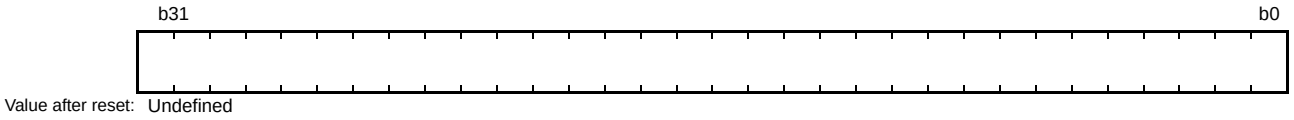
The IPL[3:0] bits specify the processor interrupt priority level as one of sixteen levels from zero to fifteen, wherein priority level zero is the lowest and priority level fifteen the highest. When the priority level of a requested interrupt is higher than the processor interrupt priority level, the interrupt is enabled. Setting the IPL[3:0] bits to level fifteen (Fh) disables all interrupt requests. The IPL[3:0] bits are set to level fifteen (Fh) when a non-maskable interrupt is generated. When interrupts in general are generated, the bits are set to the priority levels of accepted interrupts.

2.2.2.5 Backup PC (BPC)



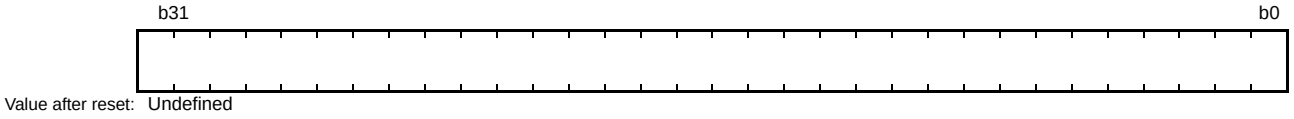
The backup PC (BPC) is provided to speed up response to interrupts.
After a fast interrupt has been generated, the contents of the program counter (PC) are saved in the BPC.

2.2.2.6 Backup PSW (BPSW)



The backup PSW (BPSW) is provided to speed up response to interrupts.
After a fast interrupt has been generated, the contents of the processor status word (PSW) are saved in the BPSW. The allocation of bits in the BPSW corresponds to that in the PSW.

2.2.2.7 Fast Interrupt Vector Register (FINTV)



The fast interrupt vector register (FINTV) is provided to speed up response to interrupts.
The FINTV register specifies a branch destination address when a fast interrupt has been generated.

2.2.2.8 Floating-Point Status Word (FPSW)

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
	FS	FX	FU	FZ	FO	FV	—	—	—	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	EX	EU	EZ	EO	EV	—	DN	CE	CX	CU	CZ	CO	CV	RM[1:0]	
Value after reset:	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1, b0	RM[1:0]	Floating-Point Rounding-Mode Setting	b1b0 0 0: Rounding to the nearest value 0 1: Rounding to 0 1 0: Rounding to +∞ 1 1: Rounding to –∞	R/W
b2	CV	Invalid Operation Cause Flag	0: No invalid operation has been encountered. 1: Invalid operation has been encountered.	R/(W)*1
b3	CO	Overflow Cause Flag	0: No overflow has occurred. 1: Overflow has occurred.	R/(W)*1
b4	CZ	Division-by-Zero Cause Flag	0: No division-by-zero has occurred. 1: Division-by-zero has occurred.	R/(W)*1
b5	CU	Underflow Cause Flag	0: No underflow has occurred. 1: Underflow has occurred.	R/(W)*1
b6	CX	Inexact Cause Flag	0: No inexact exception has been generated. 1: Inexact exception has been generated.	R/(W)*1
b7	CE	Un-Implemented Processing Cause Flag	0: No un-implemented processing has been encountered. 1: Un-implemented process has been encountered.	R/(W)*1
b8	DN	0 Flush Bit of Denormalized Number	0: A denormalized number is handled as a denormalized number. 1: A denormalized number is handled as 0.*2	R/W
b9	—	Reserved	This bit is always read as 0. The write value should be 0.	R/W
b10	EV	Invalid Operation Exception Enable	0: Invalid operation exception is masked. 1: Invalid operation exception is enabled.	R/W
b11	EO	Overflow Exception Enable	0: Overflow exception is masked. 1: Overflow exception is enabled.	R/W
b12	EZ	Division-by-Zero Exception Enable	0: Division-by-zero exception is masked. 1: Division-by-zero exception is enabled.	R/W
b13	EU	Underflow Exception Enable	0: Underflow exception is masked. 1: Underflow exception is enabled.	R/W
b14	EX	Inexact Exception Enable	0: Inexact exception is masked. 1: Inexact exception is enabled.	R/W
b25 to b15	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W
b26	FV*3	Invalid Operation Flag	0: No invalid operation has been encountered. 1: Invalid operation has been encountered.*8	R/W
b27	FO*4	Overflow Flag	0: No overflow has occurred. 1: Overflow has occurred.*8	R/W
b28	FZ*6	Division-by-Zero Flag	0: No division-by-zero has occurred. 1: Division-by-zero has occurred.*8	R/W

Bit	Symbol	Bit Name	Description	R/W
b29	FU*6	Underflow Flag	0: No underflow has occurred. 1: Underflow has occurred.*8	R/W
b30	FX*7	Inexact Flag	0: No inexact exception has been generated. 1: Inexact exception has been generated.*8	R/W
b31	FS	Floating-Point Error Summary Flag	This bit reflects the logical OR of the FU, FZ, FO, and FV flags.	R

Note 1. Writing 0 to the bit clears it. Writing 1 to the bit does not affect its value.
Note 2. Positive denormalized numbers are treated as +0, negative denormalized numbers as –0.
Note 3. When the EV bit is set to 0, the FV flag is enabled.
Note 4. When the EO bit is set to 0, the FO flag is enabled.
Note 5. When the EZ bit is set to 0, the FZ flag is enabled.
Note 6. When the EU bit is set to 0, the FU flag is enabled.
Note 7. When the EX bit is set to 0, the FX flag is enabled.
Note 8. Once the bit has been set to 1, this value is retained until it is cleared to 0 by software.

The floating-point status word (FPSW) indicates the results of floating-point operations.
When an exception handling enable bit (Ej) enables the exception handling (Ej = 1), the exception cause can be identified by checking the corresponding Cj flag in the exception handling routine. If the exception handling is masked (Ej = 0), the occurrence of exception can be checked by reading the Fj flag at the end of a series of processing. Once the Fj flag has been set to 1, this value is retained until it is cleared to 0 by software (j = X, U, Z, O, or V).

RM[1:0] bits (Floating-point rounding-mode setting)

These bits specify the floating-point rounding-mode.

Explanation of Floating-Point Rounding Modes

- Rounding to the nearest value (the default behavior): An inexact result is rounded to the available value that is closest to the result which would be obtained with an infinite number of digits. If two available values are equally close, rounding is to the even alternative.
- Rounding towards 0:An inexact result is rounded to the smallest available absolute value, i.e. in the direction of zero (simple truncation).
- Rounding towards +∞: An inexact result is rounded to the nearest available value in the direction of positive infinity.
- Rounding towards –∞: An inexact result is rounded to the nearest available value in the direction of negative infinity.

Rounding to the nearest value is specified as the default mode and returns the most accurate value.
Modes such as rounding towards 0, rounding towards +∞, and rounding towards –∞ are used to ensure precision when interval arithmetic is employed.

CV flag (Invalid operation cause flag), CO flag (Overflow cause flag), CZ flag (Division-by-zero cause flag), CU flag (Underflow cause flag), CX flag (Inexact cause flag), and CE flag (Unimplemented processing cause flag)

Floating-point exceptions include the five specified in the IEEE754 standard, namely overflow, underflow, inexact, division-by-zero, and invalid operation. For a further floating-point exception that is generated upon detection of unimplemented processing, the corresponding flag (CE) is set to 1.

- The bit that has been set to 1 is cleared to 0 when the FPU instruction is executed.
- When 0 is written to the bit by the MVTC and POPC instructions, the bit is set to 0; the bit retains the previous value when 1 is written by the instruction.

DN flag (0 flush bit of denormalized number)

When this bit is set to 0, a denormalized number is handled as a denormalized number.
When this bit is set to 1, a denormalized number is handled as 0.

EV bit (Invalid operation exception enable bit), EO bit (Overflow exception enable bit), EZ bit (Division-by-zero exception enable bit), EU bit (Underflow exception enable bit), and EX bit (Inexact exception enable bit)

When any of five floating-point exceptions specified in the IEEE754 standard is generated by the FPU instruction, the bit decides whether the CPU will start handling the exception. When the bit is set to 0, the exception handling is masked; when the bit is set to 1, the exception handling is enabled.

FV flag (Invalid operation flag), FO flag (Overflow flag), FZ flag (Division-by-zero flag), FU flag (Underflow flag), and FX flag (Inexact flag)

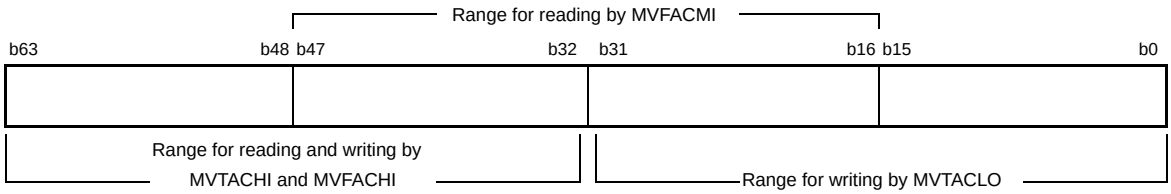
While the exception handling enable bit (Ej) is 0 (exception handling is masked), if any of five floating-point exceptions specified in the IEEE754 standard is generated, the corresponding bit is set to 1.

- When Ej is 1 (exception handling is enabled), the value of the flag remains.
- When the corresponding flag is set to 1, it remains 1 until it is cleared to 0 by software. (Accumulation flag)

FS flag (Floating-point error summary flag)

This bit reflects the logical OR of the FU, FZ, FO, and FV flags.

2.2.2.9 Accumulator (ACC)



Value after reset: Undefined

The accumulator (ACC) is a 64-bit register used for DSP instructions. The accumulator is also used for the multiply and multiply-and-accumulate instructions; EMUL, EMULU, FMUL, MUL, and RMPA, in which case the prior value in the accumulator is modified by execution of the instruction.
Use the MVTACHI and MVTACLO instructions for writing to the accumulator. The MVTACHI and MVTACLO instructions write data to the higher-order 32 bits (bits 63 to 32) and the lower-order 32 bits (bits 31 to 0), respectively.
Use the MVFACHI and MVFACMI instructions for reading data from the accumulator. The MVFACHI and MVFACMI instructions read data from the higher-order 32 bits (bits 63 to 32) and the middle 32 bits (bits 47 to 16), respectively.

2.3 Processor Mode

The RX CPU supports two processor modes, supervisor and user. These processor modes enable the realization of a hierarchical CPU resource protection.
Each processor mode imposes a level on rights of access to the CPU resource and the instructions that can be executed. Supervisor mode carries greater rights than those of user mode.
The initial state after a reset is supervisor mode.

2.3.1 Supervisor Mode

In supervisor mode, all CPU resources are accessible and all instructions are available. However, writing to the processor mode select bit (PM) in the processor status word (PSW) by executing an MVTC or a POPC instruction will be ignored. For details on how to write to the PM bit, refer to section 2, Processor Status Word (PSW).

2.3.2 User Mode

In user mode, write access to the CPU resources listed below is restricted. The restriction applies to any instruction capable of write access.

- Some bits (bits IPL[3:0], PM, U, and I) in the processor status word (PSW)
- Interrupt stack pointer (ISP)
- Interrupt table register (INTB)
- Backup PSW (BPSW)
- Backup PC (BPC)
- Fast interrupt vector register (FINTV)

2.3.3 Privileged Instruction

Privileged instructions can only be executed in supervisor mode. Executing a privileged instruction in user mode produces a privileged instruction exception. Privileged instructions include the RTFI, MVTIPL, RTE, and WAIT instructions.

2.3.4 Switching Between Processor Modes

Manipulating the processor mode select bit (PM) in the processor status word (PSW) switches the processor mode. However, rewriting to the PM bit by executing an MVTC or a POPC instruction is prohibited. Switch the processor mode by following the procedures described below.

(1) Switching from user mode to supervisor mode

After an exception has been generated, the PM bit in the PSW register is set to 0 and the CPU switches to supervisor mode. The hardware pre-processing is executed in supervisor mode. The state of the processor mode before the exception was generated is retained in the PM bit in the copy of the PSW register that is saved on the stack.

(2) Switching from supervisor mode to user mode

Executing an RTE instruction when the value of the copy of the PM bit in the PSW that has been preserved on the stack is "1" or an RTFI instruction when the value of the copy of the PM bit in the PSW that has been preserved in the backup PSW (BPSW) is "1" causes a transition to user mode. In the transition to user mode, the value of the stack pointer designation bit (the U bit in the PSW register) becomes "1".

2.4 Data Types

The RX CPU can handle four types of data: integer, floating-point, bit, and string.

2.4.1 Integer

An integer can be signed or unsigned. For signed integers, negative values are represented by two's complements.

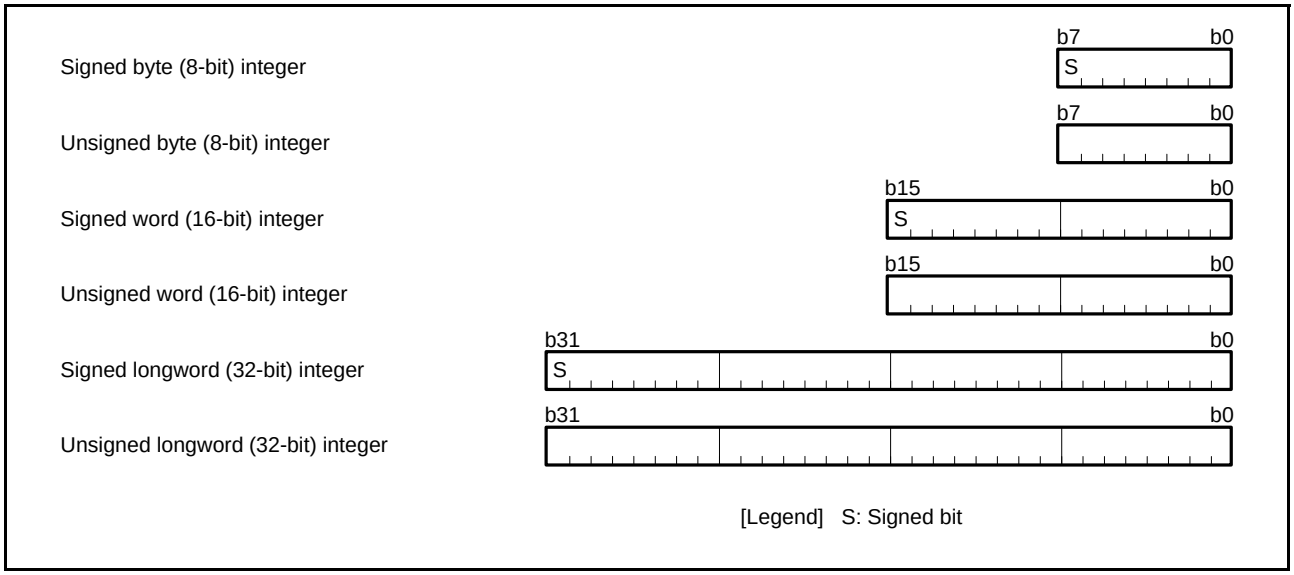


Figure 2.2 Integer

2.4.2 Floating-Point

Floating-point support is for the single-precision floating-point type specified in IEEE754; operands of this type can be used in eight floating-point operation instructions: FADD, FCMP, FDIV, FMUL, FSUB, FTOI, ITOF, and ROUND.

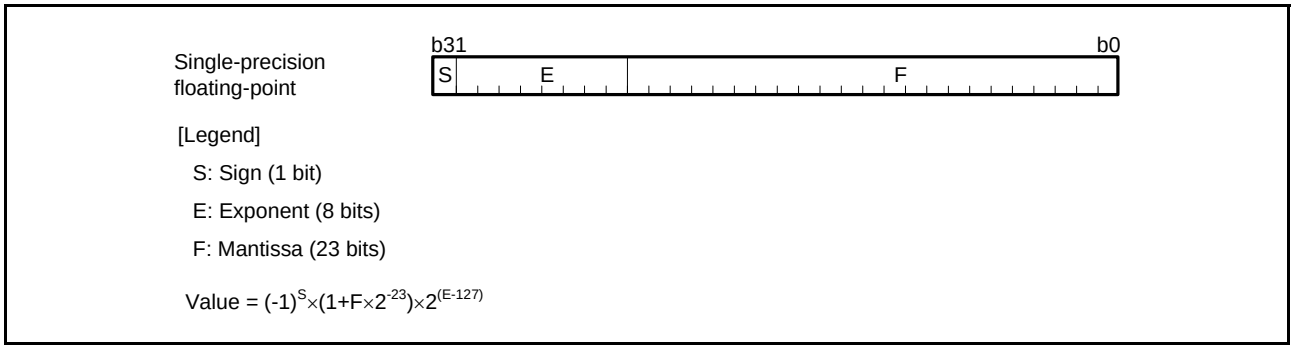


Figure 2.3 Floating-Point

The floating-point format supports the values listed below.

- 0 < E < 255 (normal numbers)
- E = 0 and F = 0 (signed zero)
- E = 0 and F > 0 (denormalized numbers)*1
- E = 255 and F = 0 (infinity)
- E = 255 and F > 0 (NaN: Not-a-Number)

Note 1. The number is treated as 0 when the DN bit in FPSW is 1. When the DN bit is 0, an un-implemented processing exception is generated.

2.4.3 Bitwise Operations

Five bit-manipulation instructions are provided for bitwise operations: BCLR, BM*Cnd*, BNOT, BSET, and BTST.
A bit in a register is specified as the destination register and a bit number in the range from 31 to 0.
A bit in memory is specified as the destination address and a bit number from 7 to 0. The addressing modes available to specify addresses are register indirect and register relative.

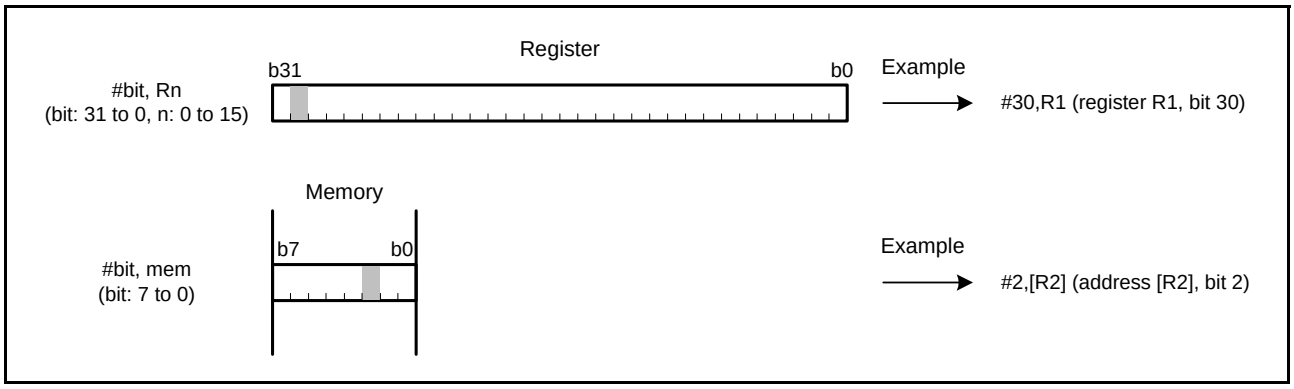


Figure 2.4 Bit

2.4.4 Strings

The string data type consists of an arbitrary number of consecutive byte (8-bit), word (16-bit), or longword (32-bit) units.
Seven string manipulation instructions are provided for use with strings: SCMPU, SMOVB, SMOVF, SMOVU, SSTR, SUNTIL, and SWHILE.

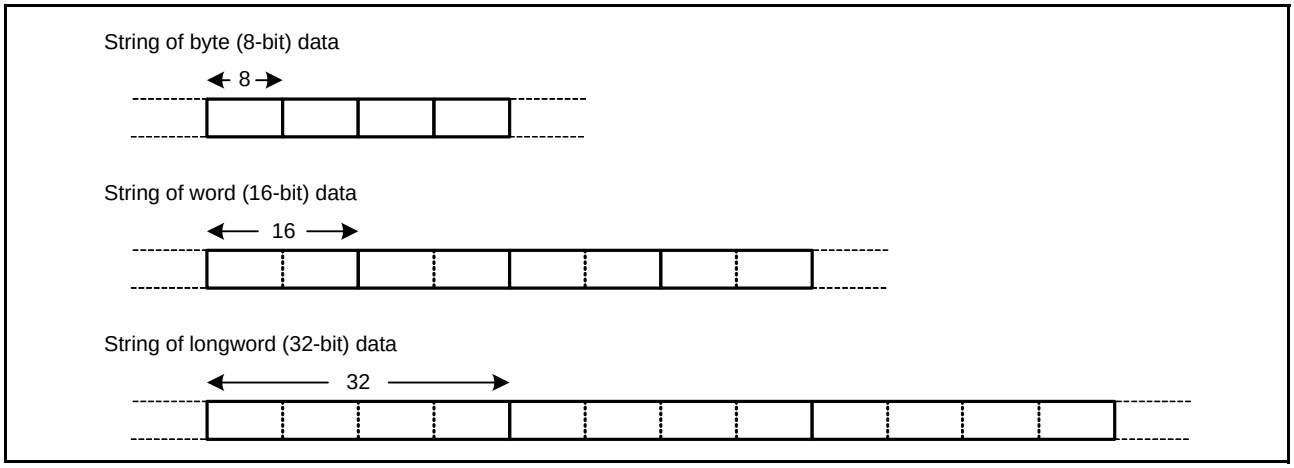


Figure 2.5 String

2.5 Endian

For the RX CPU, instructions are always little endian, but the treatment of data is selectable as little or big endian.

2.5.1 Switching the Endian

As arrangements of bytes, the RX62T Group supports both big endian, where the higher-order byte (MSB) is at location 0, and little endian, where the lower-order byte (LSB) is at location 0.
The endian is switched by changing the setting on a mode pin (MDE). For details on the endian setting, see section 3, Operating Modes.
Operations for access differ according to the endian setting and, depending on the instruction, whether 8-, 16- or 32-bit access has been selected. Operations for access in the various possible cases are described inTable 2.1 to Table 2.12.
In the tables, LL indicates bits D7 to D0 of the general register,
LH indicates bits D15 to D8 of the general register,
HL indicates bits D23 to D16 of the general register, and
HH indicates bits D31 to D24 of the general register.

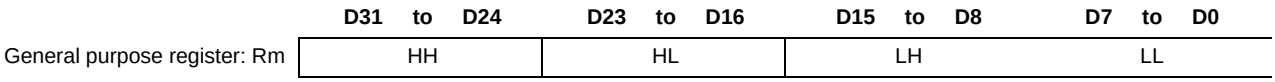


Table 2.1 32-Bit Read Operations when Little Endian has been Selected

Operation / Address of src	Reading a 32-bit unit from address 0	Reading a 32-bit unit from address 1	Reading a 32-bit unit from address 2	Reading a 32-bit unit from address 3	Reading a 32-bit unit from address 4
Address 0	Transfer to LL	—	—	—	—
Address 1	Transfer to LH	Transfer to LL	—	—	—
Address 2	Transfer to HL	Transfer to LH	Transfer to LL	—	—
Address 3	Transfer to HH	Transfer to HL	Transfer to LH	Transfer to LL	—
Address 4	—	Transfer to HH	Transfer to HL	Transfer to LH	Transfer to LL
Address 5	—	—	Transfer to HH	Transfer to HL	Transfer to LH
Address 6	—	—	—	Transfer to HH	Transfer to HL
Address 7	—	—	—	—	Transfer to HH

Table 2.2 32-Bit Read Operations when Big Endian has been Selected

Operation / Address of src	Reading a 32-bit unit from address 0	Reading a 32-bit unit from address 1	Reading a 32-bit unit from address 2	Reading a 32-bit unit from address 3	Reading a 32-bit unit from address 4
Address 0	Transfer to HH	—	—	—	—
Address 1	Transfer to HL	Transfer to HH	—	—	—
Address 2	Transfer to LH	Transfer to HL	Transfer to HH	—	—
Address 3	Transfer to LL	Transfer to LH	Transfer to HL	Transfer to HH	—
Address 4	—	Transfer to LL	Transfer to LH	Transfer to HL	Transfer to HH
Address 5	—	—	Transfer to LL	Transfer to LH	Transfer to HL
Address 6	—	—	—	Transfer to LL	Transfer to LH
Address 7	—	—	—	—	Transfer to LL

Table 2.3 32-Bit Write Operations when Little Endian has been Selected

Operation / Address of src	Writing a 32-bit unit to address 0	Writing a 32-bit unit to address 1	Writing a 32-bit unit to address 2	Writing a 32-bit unit to address 3	Writing a 32-bit unit to address 4
Address 0	Transfer from LL	—	—	—	—
Address 1	Transfer from LH	Transfer from LL	—	—	—
Address 2	Transfer from HL	Transfer from LH	Transfer from LL	—	—
Address 3	Transfer from HH	Transfer from HL	Transfer from LH	Transfer from LL	—
Address 4	—	Transfer from HH	Transfer from HL	Transfer from LH	Transfer from LL
Address 5	—	—	Transfer from HH	Transfer from HL	Transfer from LH
Address 6	—	—	—	Transfer from HH	Transfer from HL
Address 7	—	—	—	—	Transfer from HH

Table 2.4 32-Bit Write Operations when Big Endian has been Selected

Operation / Address of dest	Writing a 32-bit unit to address 0	Writing a 32-bit unit to address 1	Writing a 32-bit unit to address 2	Writing a 32-bit unit to address 3	Writing a 32-bit unit to address 4
Address 0	Transfer from HH	—	—	—	—
Address 1	Transfer from HL	Transfer from HH	—	—	—
Address 2	Transfer from LH	Transfer from HL	Transfer from HH	—	—
Address 3	Transfer from LL	Transfer from LH	Transfer from HL	Transfer from HH	—
Address 4	—	Transfer from LL	Transfer from LH	Transfer from HL	Transfer from HH
Address 5	—	—	Transfer from LL	Transfer from LH	Transfer from HL
Address 6	—	—	—	Transfer from LL	Transfer from LH
Address 7	—	—	—	—	Transfer from LL

Table 2.5 16-Bit Read Operations when Little Endian has been Selected

Operation / Address of src	Reading a 16-bit unit from address 0	Reading a 16-bit unit from address 1	Reading a 16-bit unit from address 2	Reading a 16-bit unit from address 3	Reading a 16-bit unit from address 4	Reading a 16-bit unit from address 5	Reading a 16-bit unit from address 6
Address 0	Transfer to LL	—	—	—	—	—	—
Address 1	Transfer to LH	Transfer to LL	—	—	—	—	—
Address 2	—	Transfer to LH	Transfer to LL	—	—	—	—
Address 3	—	—	Transfer to LH	Transfer to LL	—	—	—
Address 4	—	—	—	Transfer to LH	Transfer to LL	—	—
Address 5	—	—	—	—	Transfer to LH	Transfer to LL	—
Address 6	—	—	—	—	—	Transfer to LH	Transfer to LL
Address 7	—	—	—	—	—	—	Transfer to LH

Table 2.6 16-Bit Read Operations when Big Endian has been Selected

Operation / Address of src	Reading a 16-bit unit from address 0	Reading a 16-bit unit from address 1	Reading a 16-bit unit from address 2	Reading a 16-bit unit from address 3	Reading a 16-bit unit from address 4	Reading a 16-bit unit from address 5	Reading a 16-bit unit from address 6
Address 0	Transfer to LH	—	—	—	—	—	—
Address 1	Transfer to LL	Transfer to LH	—	—	—	—	—
Address 2	—	Transfer to LL	Transfer to LH	—	—	—	—
Address 3	—	—	Transfer to LL	Transfer to LH	—	—	—
Address 4	—	—	—	Transfer to LL	Transfer to LH	—	—
Address 5	—	—	—	—	Transfer to LL	Transfer to LH	—
Address 6	—	—	—	—	—	Transfer to LL	Transfer to LH
Address 7	—	—	—	—	—	—	Transfer to LL

Table 2.7 16-Bit Write Operations when Little Endian has been Selected

Operation / Address of dest	Writing a 16-bit unit to address 0	Writing a 16-bit unit to address 1	Writing a 16-bit unit to address 2	Writing a 16-bit unit to address 3	Writing a 16-bit unit to address 3	Writing a 16-bit unit to address 5	Writing a 16-bit unit to address 6
Address 0	Transfer from LL	—	—	—	—	—	—
Address 1	Transfer from LH	Transfer from LL	—	—	—	—	—
Address 2	—	Transfer from LH	Transfer from LL	—	—	—	—
Address 3	—	—	Transfer from LH	Transfer from LL	—	—	—
Address 4	—	—	—	Transfer from LH	Transfer from LL	—	—
Address 5	—	—	—	—	Transfer from LH	Transfer from LL	—
Address 6	—	—	—	—	—	Transfer from LH	Transfer from LL
Address 7	—	—	—	—	—	—	Transfer from LH

Table 2.8 16-Bit Write Operations when Big Endian has been Selected

Operation / Address of dest	Writing a 16-bit unit to address 0	Writing a 16-bit unit to address 1	Writing a 16-bit unit to address 2	Writing a 16-bit unit to address 3	Writing a 16-bit unit to address 4	Writing a 16-bit unit to address 5	Writing a 16-bit unit to address 6
Address 0	Transfer from LH	—	—	—	—	—	—
Address 1	Transfer from LL	Transfer from LH	—	—	—	—	—
Address 2	—	Transfer from LL	Transfer from LH	—	—	—	—
Address 3	—	—	Transfer from LL	Transfer from LH	—	—	—
Address 4	—	—	—	Transfer from LL	Transfer from LH	—	—
Address 5	—	—	—	—	Transfer from LL	Transfer from LH	—
Address 6	—	—	—	—	—	Transfer from LL	Transfer from LH
Address 7	—	—	—	—	—	—	Transfer from LL

Table 2.9 8-Bit Read Operations when Little Endian has been Selected

Operation / Address of src	Reading an 8-bit unit from address 0	Reading an 8-bit unit from address 1	Reading an 8-bit unit from address 2	Reading an 8-bit unit from address 3
Address 0	Transfer to LL	—	—	—
Address 1	—	Transfer to LL	—	—
Address 2	—	—	Transfer to LL	—
Address 3	—	—	—	Transfer to LL

Table 2.10 8-Bit Read Operations when Big Endian has been Selected

Operation / Address of src	Reading an 8-bit unit from address 0	Reading an 8-bit unit from address 1	Reading an 8-bit unit from address 2	Reading an 8-bit unit from address 3
Address 0	Transfer to LL	—	—	—
Address 1	—	Transfer to LL	—	—
Address 2	—	—	Transfer to LL	—
Address 3	—	—	—	Transfer to LL

Table 2.11 8-Bit Write Operations when Little Endian has been Selected

Operation / Address of dest	Writing an 8-bit unit to address 0	Writing an 8-bit unit to address 1	Writing an 8-bit unit to address 2	Writing an 8-bit unit to address 3
Address 0	Transfer from LL	—	—	—
Address 1	—	Transfer from LL	—	—
Address 2	—	—	Transfer from LL	—
Address 3	—	—	—	Transfer from LL

Table 2.12 8-Bit Write Operations when Big Endian has been Selected

Operation / Address of dest	Writing an 8-bit unit to address 0	Writing an 8-bit unit to address 1	Writing an 8-bit unit to address 2	Writing an 8-bit unit to address 3
Address 0	Transfer from LL	—	—	—
Address 1	—	Transfer from LL	—	—
Address 2	—	—	Transfer from LL	—
Address 3	—	—	—	Transfer from LL

2.5.2 Access to I/O Registers

The addresses of I/O registers are fixed, and this is regardless of whether the setting is for little endian or big endian. Accordingly, changes to the endian do not affect access to I/O registers. For the arrangements of I/O registers, refer to the descriptions of registers in the relevant sections.

2.5.3 Notes on Access to I/O Registers

Ensure that access to I/O registers is in accord with the following rules.

- For I/O registers with a bus width of eight bits, use instructions with size specifier (.size) of. B or size extension specifier (.memex) of. B or. UB.
- For I/O registers with a bus width of 16 bits, use instructions with size specifier (.size) of. W or size extension specifier (.memex) of. W or. UW.
- For I/O registers with a bus width of 32 bits, use instructions with size specifier (.size) of. L or size extension specifier (.memex) of. L.

2.5.4 Data Arrangement

2.5.4.1 Data Arrangement in Registers

Figure 2.6shows the relation between the sizes of registers and bit numbers.

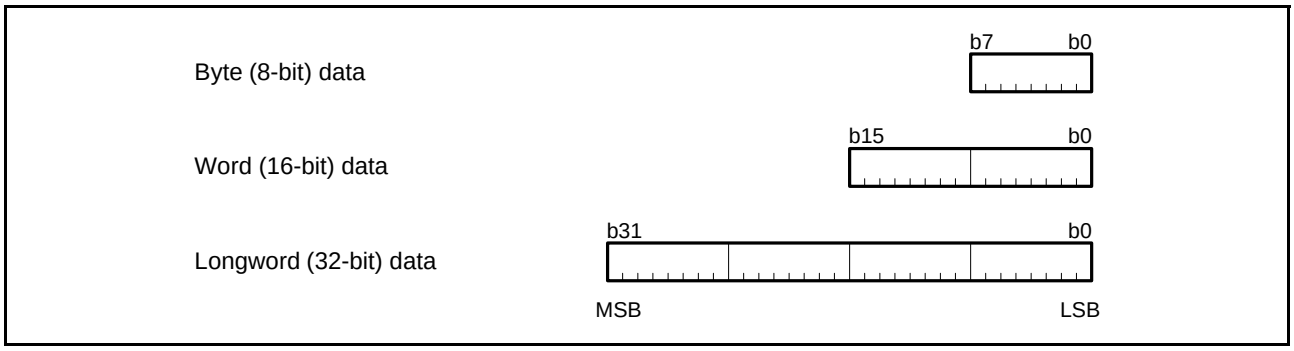


Figure 2.6 Data Arrangement in Registers

2.5.4.2 Data Arrangement in Memory

Data in memory have three sizes: byte (8-bit), word (16-bit), and longword (32-bit). The data arrangement is selectable as little endian or big endian. Figure 2.7 shows the arrangement of data in memory.

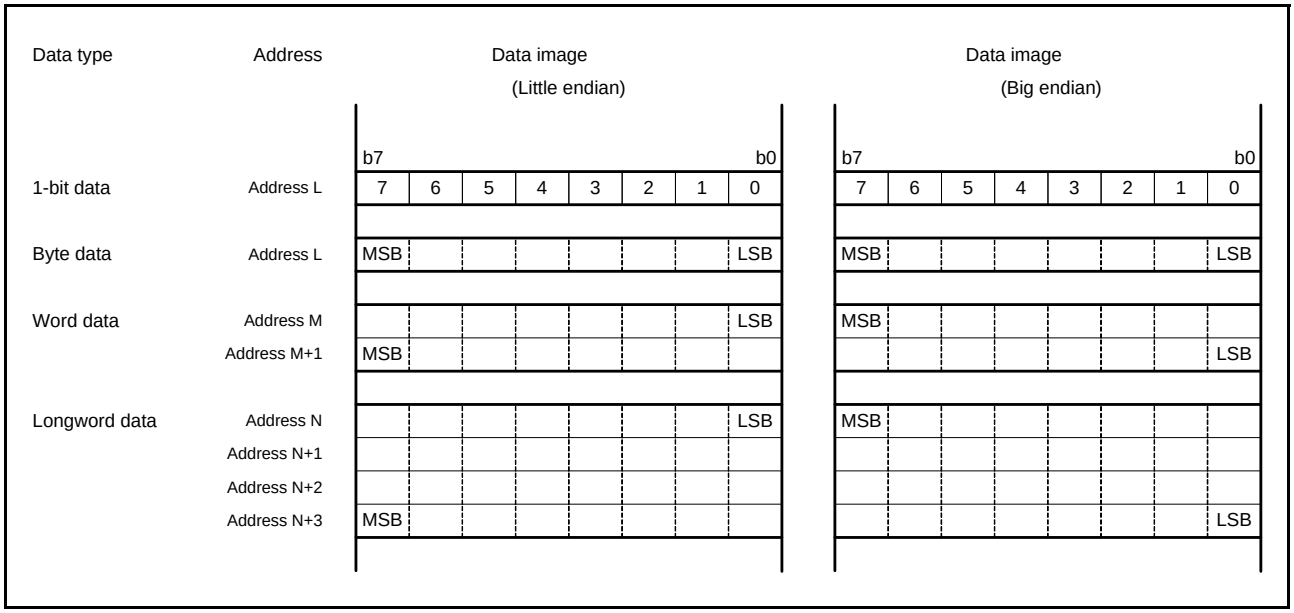


Figure 2.7 Data Arrangement in Memory

2.6 Vector Table

There are two types of vector table: fixed and relocatable. Each vector in the vector table consists of four bytes and specifies the address where the corresponding exception handling routine starts.

2.6.1 Fixed Vector Table

The fixed vector table is allocated to a fixed address range. The individual vectors for the privileged instruction exception, undefined instruction exception, floating-point exception, non-maskable interrupt, and reset are allocated to addresses in the range from FFFFFF80h to FFFFFFFFh. Figure 2.8 shows the fixed vector table.

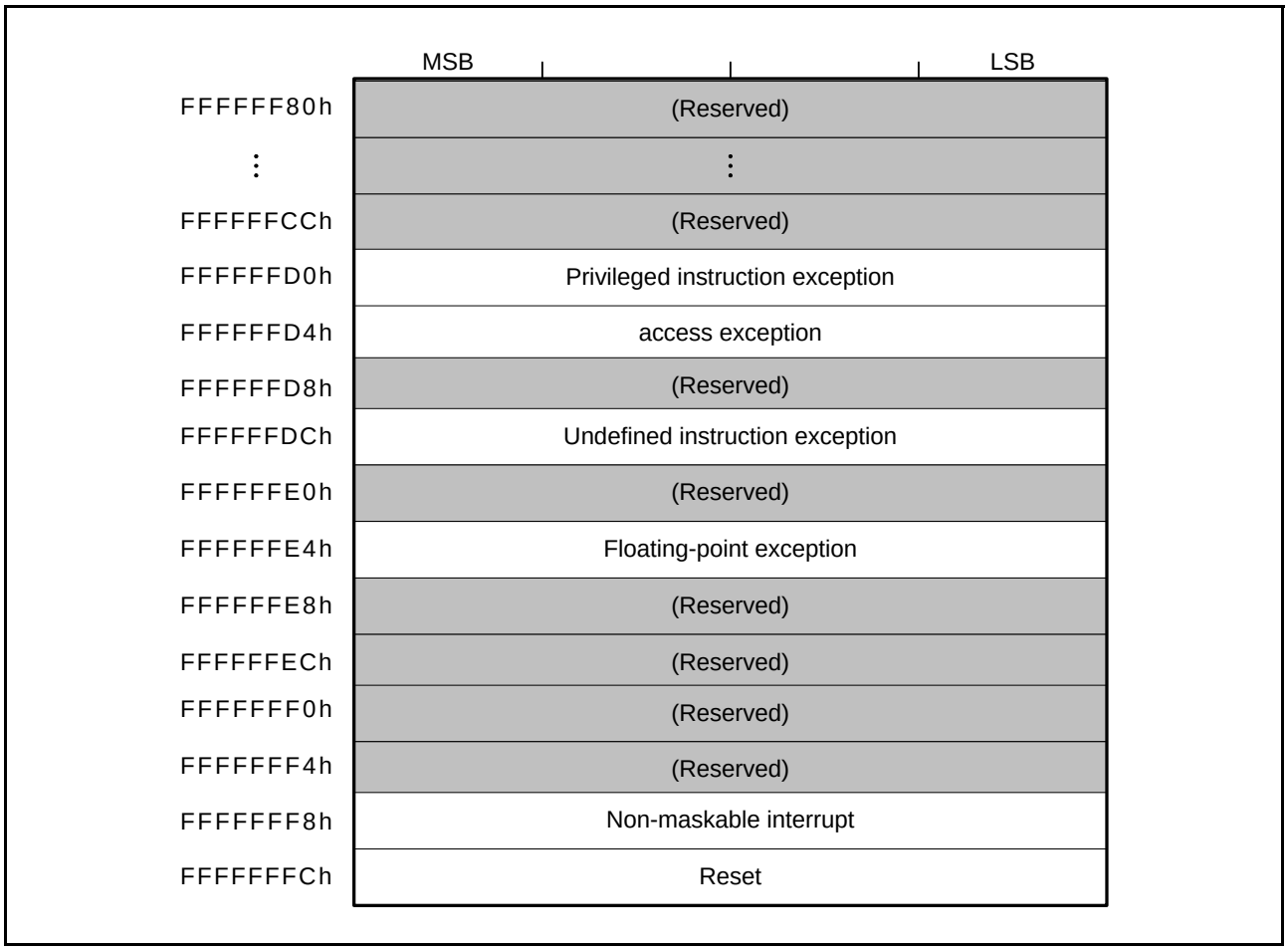


Figure 2.8 Fixed Vector Table

2.6.2 Relocatable Vector Table

The address where the relocatable vector table is placed can be adjusted. The table is a 1,024-byte region that contains all vectors for unconditional traps and interrupts and starts at the address (IntBase) specified in the interrupt table register (INTB). Figure 2.9 shows the relocatable vector table.

Each vector in the relocatable vector table has a vector number from 0 to 255. Each of the INT instructions, which act as the sources of unconditional traps, is allocated to the vector that has the same number as that of the instruction itself (from 0 to 255). The BRK instruction is allocated to the vector with number 0. Furthermore, vector numbers within the set from 0 to 255 may also be allocated to other interrupt sources on a per-product basis. For more on the interrupt vector numbers, see section 11, Interrupt Controller (ICU).

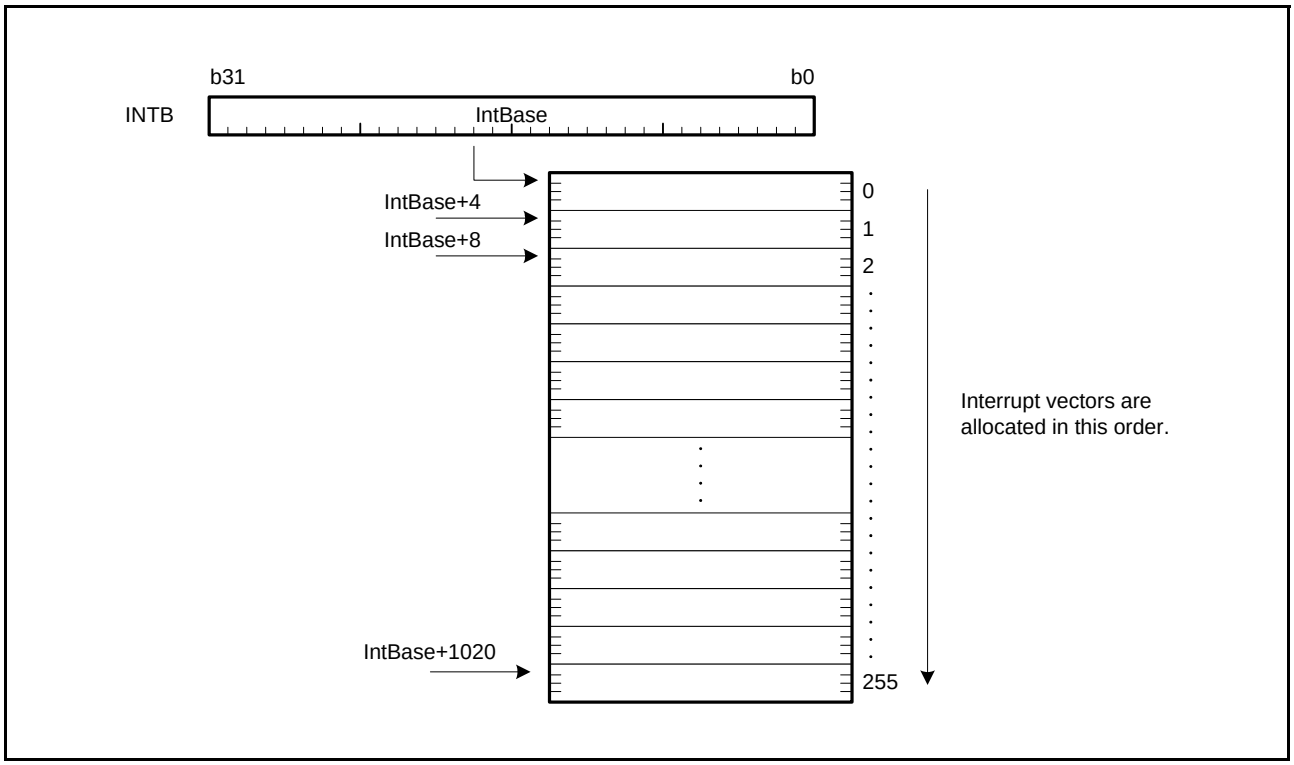


Figure 2.9 Relocatable Vector Table

2.7 Operation of Instructions

2.7.1 Data Prefetching by the RMPA Instruction and the String-Manipulation Instructions

The RMPA instruction and the string-manipulation instructions except the SSTR instruction (that is, SCMPU, SMOVB, SMOVF, SMOVU, SUNTIL, and SWHILE instructions) may prefetch data from the memory to speed up the read processing. Data is prefetched from the prefetching start position with three bytes as the upper limit. The prefetching start positions of each operation are shown below.

- RMPA instruction: The multiplicand address specified by R1, and the multiplier address specified by R2
- SCMPU instruction: The source address specified by R1 for comparison, and the destination address specified by R2 for comparison
- SUNTIL and SWHILE instructions: The destination address specified by R1 for comparison
- SMOVB, SMOVF, and SMOVU instructions: The source address specified by R2 for transfer

2.8 Pipeline

2.8.1 Overview

The RX CPU has 5-stage pipeline structure. The RX CPU instruction is converted into one or more micro-operations, which are then executed in pipeline processing. In the pipeline stage, the IF stage is executed in the unit of instructions, while the D and subsequent stages are executed in the unit of micro-operations.
The operation of pipeline and respective stages is described below.

(1) IF stage (instruction fetch stage)

In the IF stage, the CPU fetches instructions from the memory. As the RX CPU has four 8-byte instruction queues, it fetches instructions until the instruction queue is full, regardless of the completion of decoding in the D (decoding) stage.

(2) D stage (decoding stage)

The CPU decodes instructions in the D stage and converts them into micro-operations. The CPU reads the register information (RF) in this stage and executes a bypass process (BYP) if the result of the preceding instruction will be used in a subsequent instruction. The write of operation result to the register (RW) can be executed with the register reference by using the bypass process.

(3) E stage (execution stage)

Operations and address calculations (OP) are processed in the E stage.

(4) M stage (memory access stage)

Operand memory accesses (OA) are processed in the M stage. This stage is used only when the memory is accessed, and is divided into two sub-stages, M1 and M2. The RX CPU enables respective memory accesses for M1 and M2.

- M1 stage (memory-access stage 1)
  Operand memory access (OA1, OA2) is processed.
  Store operation: The pipeline processing ends when a write request is received via the bus.
  Load operation: The operation proceeds to the M2 stage when a read request is received via the bus. If a request and load data are received at the same timing (no-wait memory access), the operation proceeds to the WB stage.
- M2 stage (memory-access stage 2)
  Operand memory access (OA2) is processed. The CPU waits for the load data in the M2 stage. When the load data is received, the operation proceeds to the WB stage.

(5) WB stage (write-back stage)

The operation result and the data read from memory are written to the register (RW) in the WB stage. The data read from memory and the other type of data, such as the operation result, can be written to the register in the same clock cycles.

Figure 2.10 shows the pipeline configuration and its operation.

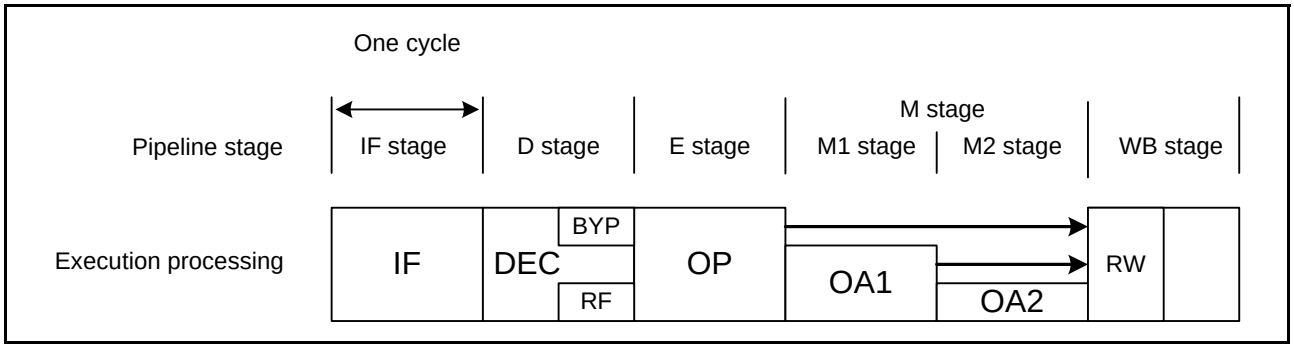


Figure 2.10 Pipeline Configuration and its Operation

2.8.2 Instructions and Pipeline Processing

The operands in the table below indicate the following meaning.
#IMM: Immediate
Rs, Rs2, Rd, Rd2, Ri, Rb: General-purpose register, CR: Control register
dsp: dsp5, dsp8, dsp16, dsp24
pcdsp: pcdsp3, pcdsp8, pcdsp16, pcdsp24

2.8.2.1 Instructions Converted into Single Micro-Operation and Pipeline Processing

The table below lists the instructions that are converted into a single micro-operation. The number of cycles in the table indicates the number of cycles during no-wait memory access.

Table 2.13 Instructions that are Converted into a Single Micro-Operation

Instruction	Mnemonic (indicates the common operation when the size is omitted)	Reference Figure	Number of Cycles
Arithmetic/logic instructions (register-register, immediate-register) Except EMUL, EMULU, RMPA, DIV, DIVU, and SATR	• {ABS, ADC, ADD, AND, CMP, MAX, MIN, MUL, NEG,NOP, NOT, OR, ROLC, RORC, ROTL, ROTR, SAT,SBB, SHAR, SHLL, SHLR, SUB, TST, XOR} “#IMM,Rd”/“Rd” / “Rs, Rd”/“Rs, Rs2, Rd”	Figure 2.11	1
Arithmetic/logic instructions (division)	• DIV “#IMM, Rd”/“Rs, Rd”	Figure 2.11	3 to 20*1
	• DIVU “#IMM, Rd”/“Rs, Rd”	Figure 2.11	2 to 18*1
Data transfer instructions (register-register, immediate-register)	• {MOV, MOVU, REVL, REVW} “#IMM, Rd”/ “Rs, Rd” • SC*Cnd* “Rd” • {STNZ, STZ} “#IMM, Rd”	Figure 2.11	1
Transfer instructions (load operation)	• {MOV, MOVU} “[Rs], Rd”/“dsp[Rs], Rd” / “[Rs+], Rd”/“[-Rs], Rd”/“Rs, [Ri, Rb]” • POP “Rd”	Figure 2.12	Throughput: 1 Latency: 2*2
Transfer instructions (store operation)	• MOV “Rs, [Rd]”/“Rs, dsp[Rd]”/“Rs, [Rd+]” / “Rs, [-Rd]”/“Rs, [Ri, Rb]” • PUSH “Rs” • PUSHC “CR”	Figure 2.13	1
Bit manipulation instructions (register)	• {BCLR, BNOT, BSET, BTST} “#IMM, Rd”/ “Rs, Rd” • BM*Cnd* “#IMM, Rd”	Figure 2.11	1
Branch instructions	• B*Cnd* “pcdsp” • {BRA, BSR} “pcdsp”/“Rs” • {JMP, JSR} “Rs”	Figure 2.22	Branch taken: 3 Branch not taken: 1
Floating-point operation instructions (register-register, immediate-register)	• FCMP “#IMM, Rd”/“Rs, Rd”	Figure 2.11	1
System manipulation instructions	• CLRPSW, SETPSW “#IMM” • MVTC “#IMM, CR”/“Rs, CR” • MVFC “CR, Rd” • MVTIPL “#IMM”	—	1
DSP function instructions	• {MACHI, MACLO, MULHI, MULLO}“Rs, Rs2” • {MVFACHI, MVFACMI}“Rd” • {MVTACHI, MVTACLO}“Rs” • RACW“#IMM”	Figure 2.11	1

Note 1. The number of cycles for the dividing instruction varies according to the divisor and dividend.
Note 2. For the number of cycles for throughput and latency, see section 2.8.3, Calculation of the Instruction Processing Time.

Figure 2.11 to Figure 2.13show the operation of instructions that are converted into a basic single micro-operation.

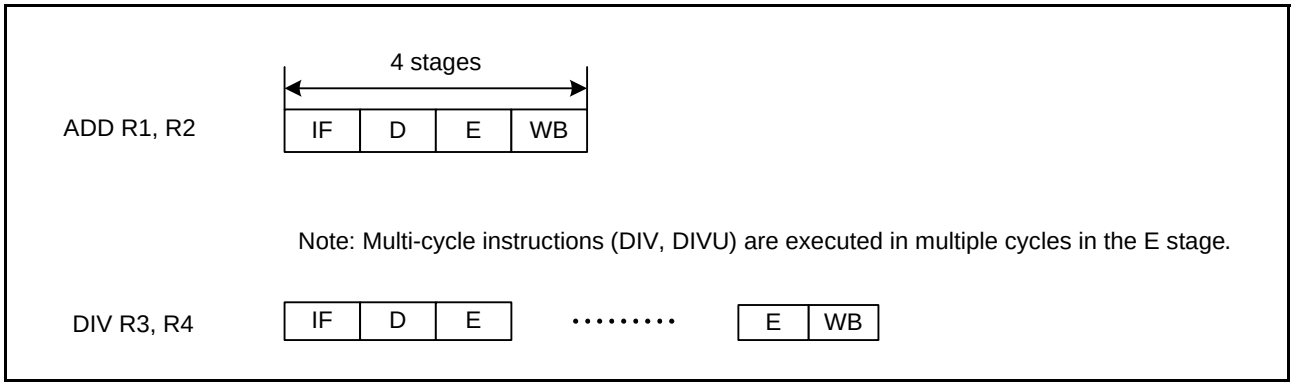


Figure 2.11 Operation for Register-Register, Immediate-Register

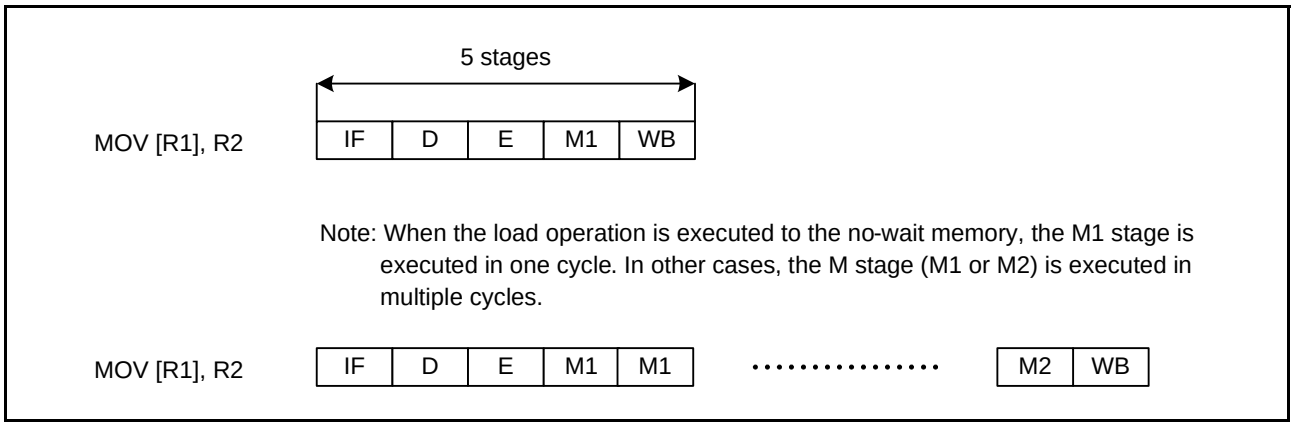


Figure 2.12 Load Operation

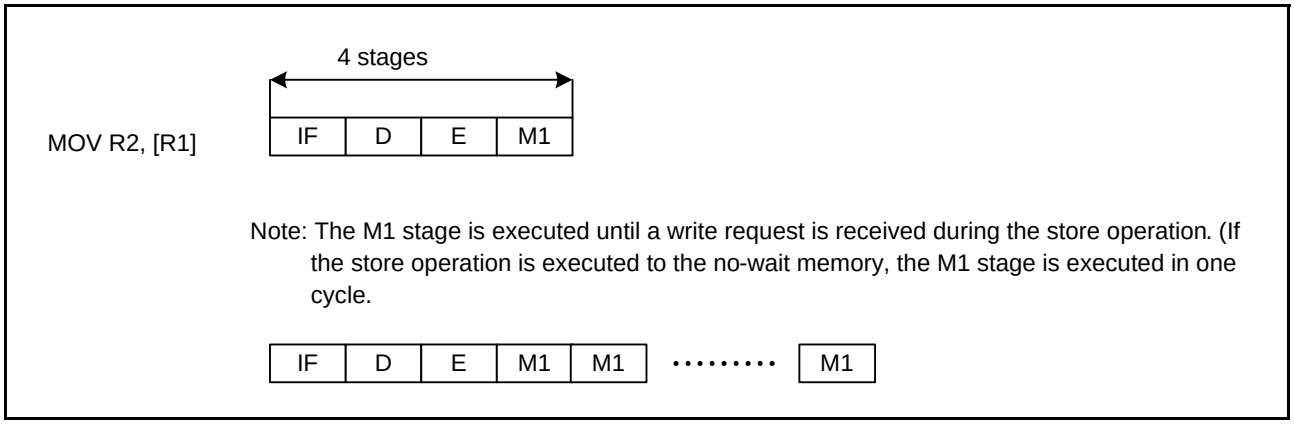


Figure 2.13 Store Operation

2.8.2.2 Instructions Converted into Multiple Micro-Operations and Pipeline Processing

The table below lists the instructions that are converted into multiple micro-operations. The number of cycles in the table indicates the number of cycles during no-wait memory access.

Table 2.14 Instructions that are Converted into Multiple Micro-Operations (1 / 2)

Instruction	Mnemonic (indicates the common operation when the size is omitted)	Reference Figure	Number of Cycles
Arithmetic/logic instructions (memory source operand)	• {ADC, ADD, AND, CMP, MAX, MIN, MUL, OR, SBB, SUB, TST, XOR} “[Rs], Rd” / “dsp[Rs], Rd”	Figure 2.14	3
Arithmetic/logic instructions (division)	• DIV “[Rs], Rd/dsp[Rs], Rd”	—	5 to 22
	• DIVU ”[Rs], Rd/dsp[Rs], Rd”	—	4 to 20
Arithmetic/logic instructions (multiplier: 32 x 32 → 64 bits) (register-register, register-immediate)	• {EMUL, EMULU} “#IMM, Rd”/“Rs, Rd”	Figure 2.16	2
Arithmetic/logic instructions (multiply-and-accumulate operation)	• RMPA.B	—	6+7×floor(n/4)+4×(n%4) n: Number of processing bytes*1
	• RMPA.W	—	6+5×floor(n/2)+4×(n%2) n: Number of processing words*1
	• RMPA.L	—	6+4n n: Number of processing longwords*1
Arithmetic/logic instructions (64-bit signed saturation for RMPA instruction)	• SATR	—	3
Data transfer instructions (memory-memory transfer)	• MOV “[Rs], [Rd]”/“dsp[Rs], [Rd]” /“[Rs], dsp[Rd]”/“dsp[Rs], [Rd]” • PUSH “[Rs]”/“dsp[Rs]”	Figure 2.15	3
Bit manipulation instructions (memory source operand)	• {BCLR, BNOT, BSET, BTST} “#IMM, [Rd]” /“#IMM, dsp[Rd]” • BM*Cnd* “#IMM, [Rd]”/“#IMM, dsp[Rd]”	Figure 2.15	3
Transfer instructions (load operation)	• POPC “CR”	—	Throughput: 3 Latency: 4*2
Transfer instructions (store operation of multiple registers)	• PUSHM “Rs-Rs2”	—	n n: Number of registers*3
Transfer instructions (store operation of multiple registers)	• POPM “Rs-Rs2”	—	Throughput: n Latency: n + 1 n: Number of registers*2*4
Transfer instructions (register-register)	• XCHG “Rs, Rd”	Figure 2.17	2
Transfer instructions (memory-register)	• XCHG “[Rs], Rd”/“dsp[Rs], Rd”	Figure 2.18	2
Branch instructions	• RTS	—	5
	• RTSD “#IMM”	—	5
	• RTSD “#IMM, Rd-Rd2”	—	Throughput: n<5?5:1+n Latency: n<4?5:2+n n: Number of registers*2

Table 2.14 Instructions that are Converted into Multiple Micro-Operations (2 / 2)

Instruction	Mnemonic (indicates the common operation when the size is omitted)	Reference Figure	Number of Cycles
String manipulation instructions*5	• SCMPU	—	2+4×floor(n/4)+4×(n%4) n: Number of comparison bytes*1
	• SMOVB	—	n>3? 6+3×floor(n/4)+3×(n%4): 2+3n n: Number of transfer bytes*1
	• SMOVF, SMOVU	—	2+3×floor(n/4)+3×(n%4) n: Number of transfer bytes*1
	• SSTR.B	—	2+floor(n/4)+n%4 n: Number of transfer bytes*1
	• SSTR.W	—	2+floor(n/2)+n%2 n: Number of transfer words*1
	• SSTR.L	—	2+n n: Number of transfer longwords
	• SUNTIL.B, SWHILE.B	—	3+3×floor(n/4)+3×(n%4) n: Number of comparison bytes*1
	• SUNTIL.W, SWHILE.W	—	3+3×floor(n/2)+3×(n%2) n: Number of comparison words*1
	• SUNTIL.L, SWHILE.L	—	3+3×n n: Number of comparison longwords
Floating-point operation instructions (register-register, immediate-register)	• {FADD, FSUB} “#IMM, Rd”/ “Rs, Rd”	Figure 2.19	4
	• FMUL “#IMM, Rd”/“Rs, Rd”	—	3
	• FDIV “#IMM, Rd”/“Rs, Rd”	—	16
	• {FTOI, ROUND, ITOF} “Rs, Rd”	—	2
Floating-point operation instructions (memory source operand)	• {FADD, FSUB} “[Rs], Rd”/“dsp[Rs], Rd”	—	6
	• FMUL “[Rs], Rd”/“dsp[Rs], Rd”	—	5
	• FDIV “[Rs], Rd”/“dsp[Rs], Rd”	—	18
	• {FTOI, ROUND, ITOF} “[Rs], Rd” / “dsp[Rs], Rd”	—	4
System manipulation instructions	• RTE	—	6
	• RTFI	—	3

Note 1. floor(x): Max. integer that is smaller than x
Note 2. For the number of cycles for throughput and latency, see section 2.8.3, Calculation of the Instruction Processing Time.
Note 3. The PUSHM instruction is converted into multiple store operations. The pipeline processing is the same as the one for the store operations of the MOV instruction, where the operation is repeated for the number of specified registers.
Note 4. The POPM instruction is converted into multiple store operations. The pipeline processing is the same as the one for the store operations of the MOV instruction, where the operation is repeated for the number of specified registers.
Note 5. Each of the SCMPU, SMOVU, SWHILE, and SUNTIL instructions ends the execution regardless of the specified cycles, if the end condition is satisfied during execution.

Figure 2.14 to Figure 2.19 show the operation of instructions that are converted into basic multiple micro-operations. Small letters in figures below indicate micro-operations.

Note 1. mop: Micro-operation, stall: Pipeline stall

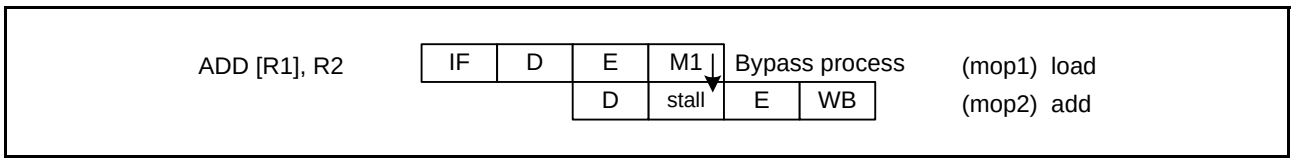


Figure 2.14 Arithmetic/Logic Instruction (Memory Source Operand)

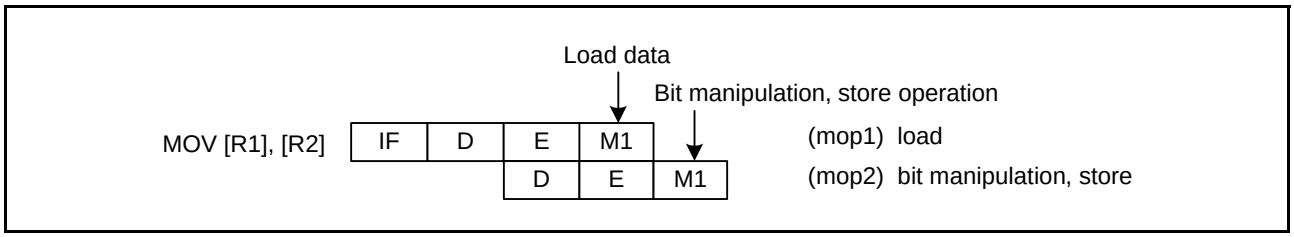


Figure 2.15 MOV Instruction (Memory-Memory), Bit Manipulation Instruction (Memory Source Operand)

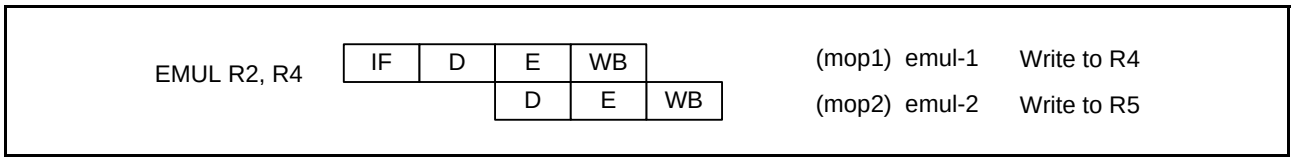


Figure 2.16 EMUL, EMULU Instructions (Register- Register, Register-Immediate)

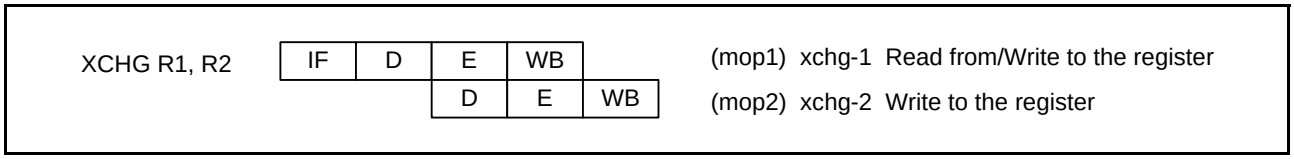


Figure 2.17 XCHG Instruction (Registers)

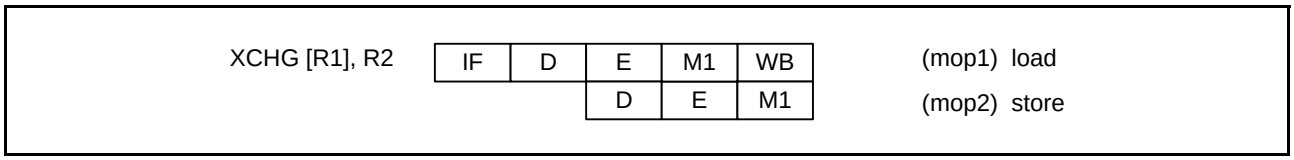


Figure 2.18 XCHG Instruction (Memory Source Operand)

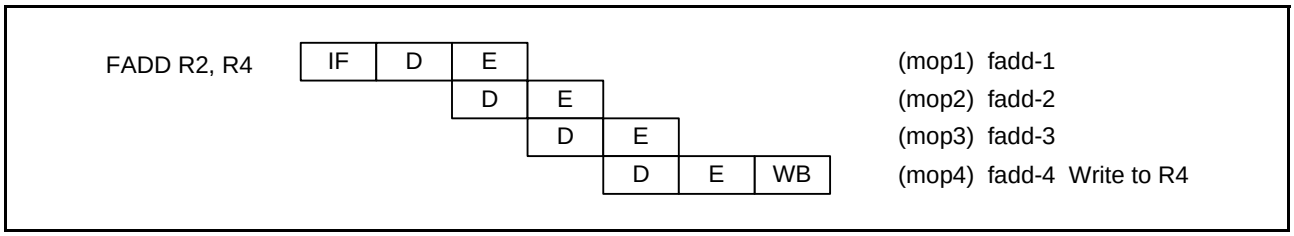


Figure 2.19 Floating-Point Operation Instruction (Register-Register, Immediate-Register)

2.8.2.3 Pipeline Basic Operation

In the ideal pipeline processing, each stage is executed in one cycle, though all instructions may not be pipelined in due to the processing and the branch execution.
The CPU controls the pipeline stage with the IF stage in the unit of instructions, while the D and subsequent stages in the unit of micro-operations.
The figures below show the pipeline processing of typical cases. Small letters in figures indicate micro-operations.
Note 1. mop: Micro-operation, stall: Pipeline stall

(1) Pipeline Flow with Stalls

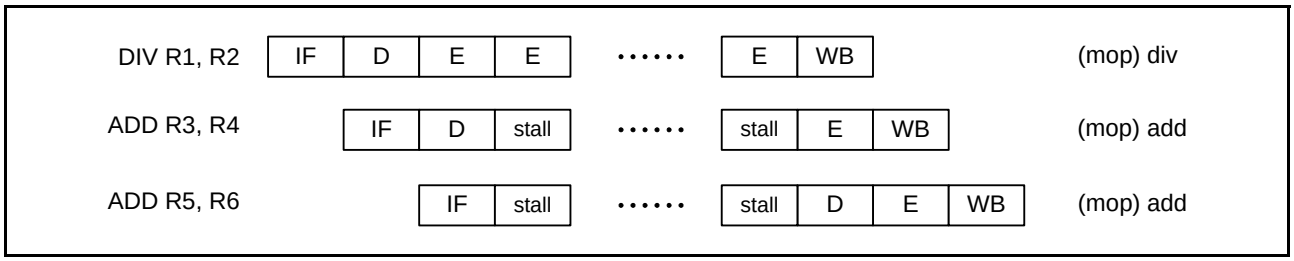


Figure 2.20 When an Instruction which Requires Multiple Cycles is Executed in the E Stage

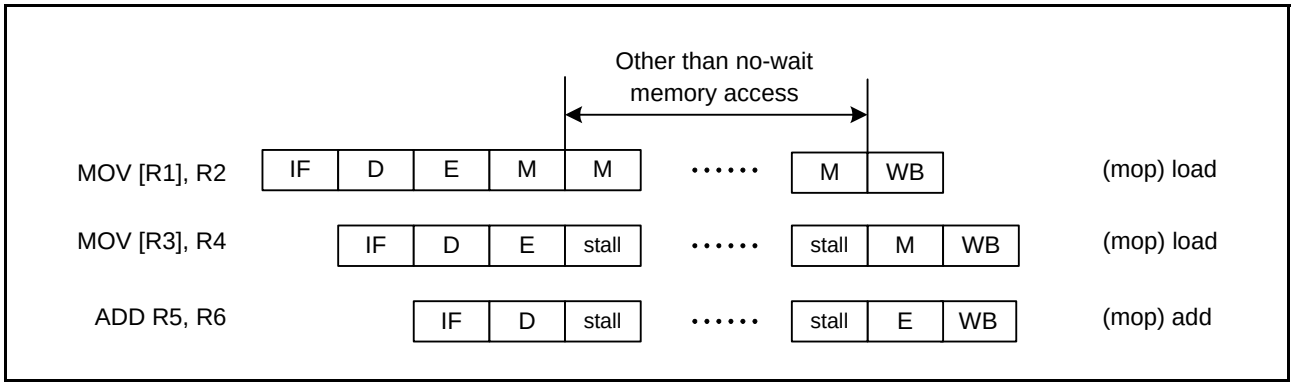


Figure 2.21 When an Instruction which Requires more than One Cycle for its Operand Access is Executed

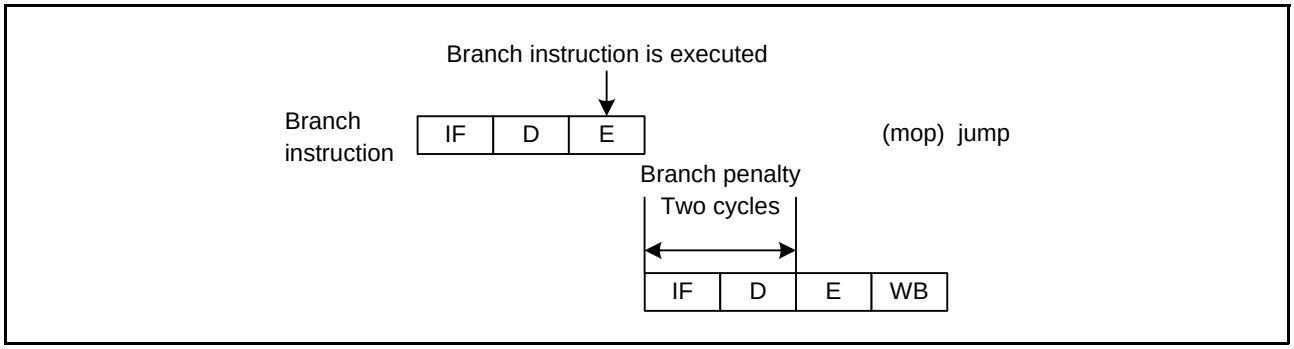


Figure 2.22 When a Branch Instruction is Executed (While the Condition is Satisfied for Unconditional/ Conditional Branch Instruction)

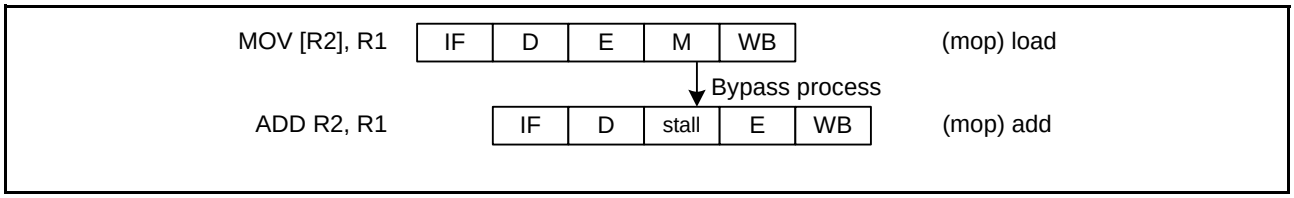


Figure 2.23 When the Subsequent Instruction Uses an Operand Read from the Memory

(2) Pipeline Flow with no Stall

(a) Bypass process

Even when the result of the preceding instruction will be used in a subsequent instruction, the operation processing between registers is pipelined in by the bypass process.

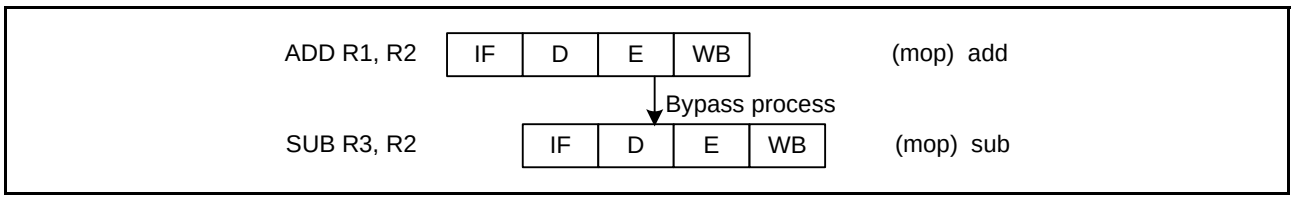


Figure 2.24 Bypass Process

(b) When WB stages for the memory load and for the operation are overlapped

Even when the WB stages for the memory load and for the operation are overlapped, the operation processing is pipelined in, because the load data and the operation result can be written to the register at the same timing.

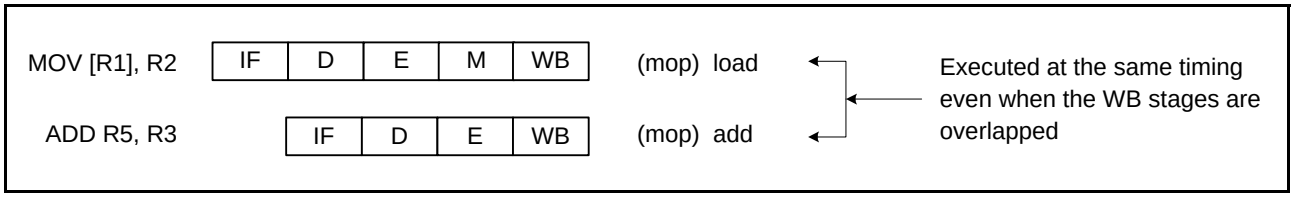


Figure 2.25 When WB Stages for the Memory Load and for the Operation are Overlapped

(c) When subsequent instruction writes to the same register before the end of memory load

Even when the subsequent instruction writes to the same register before the end of memory load, the operation processing is pipelined in, because the WB stage for the memory load is canceled.

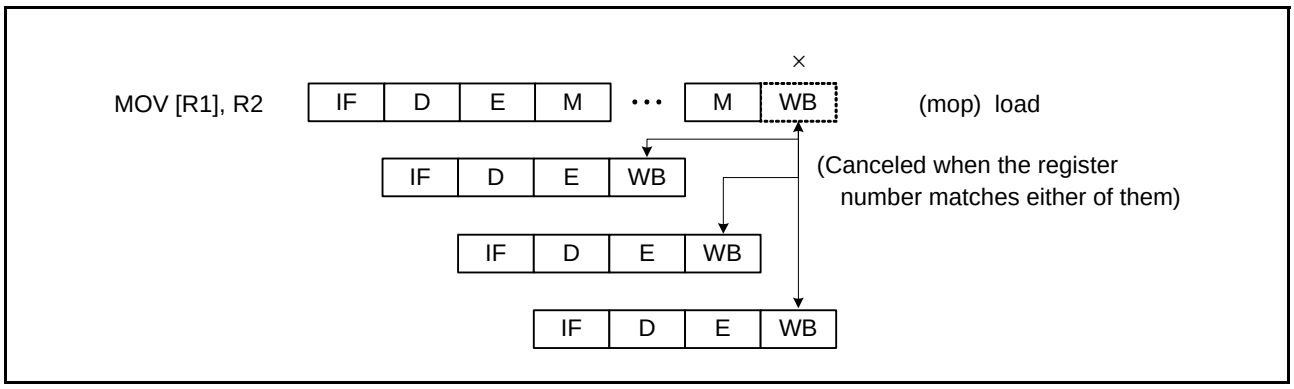


Figure 2.26 When Subsequent Instruction Writes to the Same Register before the End of Memory Load

(d) When the load data is not used by the subsequent instruction

When the load data is not used by the subsequent instruction, the subsequent operations are in fact executed earlier and the operation processing ends (out-of-order completion).

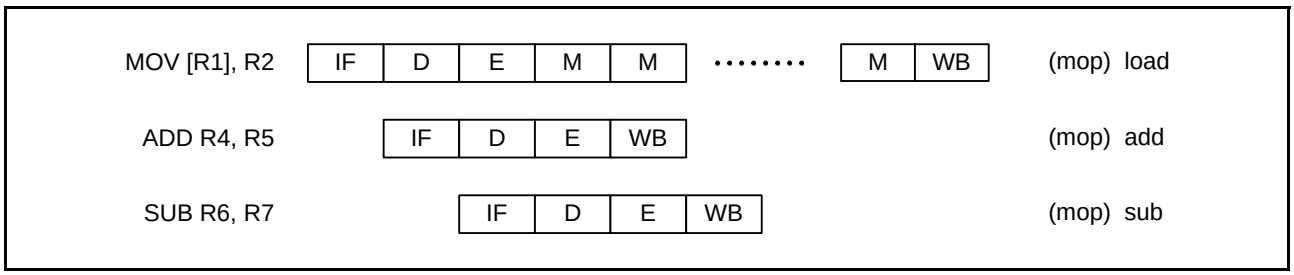


Figure 2.27 When Load Data is not Used by the Subsequent Instruction

2.8.3 Calculation of the Instruction Processing Time

Though the instruction processing time of the CPU varies according to the pipeline processing, the approximate time can be calculated in the following methods.

- Count the number of cycles (see Figure 2.13 and Figure 2.14)
- When the load data is used by the subsequent instruction, the number of cycles described as "latency" is counted as the number of cycles for the memory load instruction. For the cycles other than the memory load instruction, the number of cycles described as "throughput" is counted.
- If the instruction fetch stall is generated, the number of cycles increments.
- Depending on the system configuration, multiple cycles are required for the memory access. The number of memory access cycles in the RX62T Group is on a per-product basis.

2.8.4 Numbers of Cycles for Response to Interrupts

Table 2.15 lists numbers of cycles taken by processing for response to interrupts.

Table 2.15 Numbers of Cycles for Response to Interrupts

Type of Interrupt Request/Details of Processing	Fast Interrupt	Other Interrupts
ICU Judgment of priority order	2 cycles	2 cycles
CPU Number of cycles from notification to acceptance of the interrupt request	N cycles (varies with the instruction being executed at the time the interrupt was received)	
CPU—Pre-processing by hardware Saving the current PC and PSW values in RAM (or in control registers in the case of the fast interrupt) Reading of the vector Branching to the start of the exception handling routine	4 cycles	6 cycles

Times calculated from the values in Table 2.15 will be applicable when access to memory from the CPU is always processed with no waiting. The on-chip RAM and ROM in products of the RX62T Groups always allows such access. Numbers of cycles for response to interrupts can be minimized by placing program code (and vectors) in on-chip ROM and the stack in on-chip RAM. Furthermore, place the addresses where the exception handling routine starts on eight-byte boundaries.

For information on the number of cycles from notification to acceptance of the interrupt request, indicated by N in the table above, seeTable 2.13, Instructions that are Converted into a Single Micro-Operation, and Table 2.14, Instructions that are Converted into Multiple Micro-Operations.

The timing of interrupt acceptance depends on the state of the pipelines. For more information on this, see section 10.3.1, Timing of Acceptance and Saved PC Values.

3. Operating Modes

3.1 Operating Mode Types and Selection

The RX62T Group has two types of operating modes. Operating modes are specified by the MD1 and MD0 pins and the ROME bit in the system control register 0 (SYSCR0).
The endian of the RX62T Group can be selected in each operating mode setting. Endian is specified by the MDE pin. For the endian of the RX62T Group, see section 2.5, Endian.

Note:Do not change the state of pins MDE, MD1, and MD0 while the LSI is working. Do not select any combination other than those specified in Table 3.1.

Table 3.1 Selection of Operating Modes by the Mode Pins

Mode Pin		SYSCR0 Initial State		
MD1	**MD0**	**ROME**	**Operating Mode**	**On-Chip ROM*1**
0	1	1	Boot mode	Enabled
1	1	1	Single-chip mode	Enabled

Note 1. The on-chip ROM is classified into two flash memories: ROM and data flash. For details, see section 31, ROM (Flash Memory for Code Storage), and section 32, Data Flash Memory (Flash Memory for Data Storage).

Table 3.2 Selection of Operating Modes by Register Setting

SYSCR0		
ROME	**Operating Mode**	**On-Chip ROM*1**
0	Single-chip mode	Disabled
1		Enabled

Note 1. The on-chip ROM is classified into two flash memories: ROM and data flash. For details, see section 31, ROM (Flash Memory for Code Storage), and section 32, Data Flash Memory (Flash Memory for Data Storage).

Table 3.3 Selection of Endian

Mode Pin	
MDE	**Endian**
0	Little endian
1	Big endian

3.2 Register Descriptions

Table 3.4 lists the registers related to operating modes.

Table 3.4 Registers Related to Operating Modes

Register Name	Symbol	Value after Reset	Address	Access Size
Mode monitor register	MDMONR	10000000 x00000xxb	0008 0000h	16
Mode status register	MDSR	00000000 00001001b	0008 0002h	16
System control register 0	SYSCR0	00000000 00000001b	0008 0006h	16
System control register 1	SYSCR1	00000000 00000001b	0008 0008h	16

Note: • x:Undefined

3.2.1 Mode Monitor Register (MDMONR)

Address: 0008 0000h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	MDE	—	—	—	—	—	MD1	MD0
Value after reset:	0	0	0	0	0	0	0	0	x*1	0	0	0	0	0	x*1	x*1

Note 1. Depends on the setting of the mode pin (MD). When the MD pin is low, the bit value is 0; otherwise, the bit value is 1.

Bit	Symbol	Bit Name	Description	R/W
b0	MD0	MD0 Status Flag	0: The MD0 pin is 0 1: The MD0 pin is 1	R
b1	MD1	MD1 Status Flag	0: The MD1 pin is 0 1: The MD1 pin is 1	R
b6 to b2	—	Reserved	These bits are always read as 0. Writing to these bits has no effect.	R
b7	MDE	MDE Status Flag	0: The MDE pin is 0 (little endian) 1: The MDE pin is 1 (big endian)	R
b14 to b8	—	Reserved	These bits are always read as 0. Writing to these bits has no effect.	R
b15	—	Reserved	This bit is always read as 1. Writing to this bit has no effect.	R

MDMONR indicates the status of the mode pins.

3.2.2 Mode Status Register (MDSR)

Address: 0008 0002h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	—	—	—	BOTS	—	—	—	IROM
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	x	1	0	0	1

Bit	Symbol	Bit Name	Description	R/W
b0	IROM	On-Chip ROM Startup Status Flag	0: The on-chip ROM is disabled 1: The on-chip ROM is enabled	R
b2, b1	—	Reserved	These bits are always read as 0. Writing to these bits has no effect.	R
b3	—	Reserved	This bit is always read as 1. Writing to this bit has no effect.	R
b4	BOTS	Boot Mode Startup Flag	0: Started with a mode except boot mode 1: Started with boot mode	R
b15 to b5	—	Reserved	These bits are always read as 0. Writing to these bits has no effect.	R

MDSR indicates the internal status of this LSI at startup.

3.2.3 System Control Register 0 (SYSCR0)

Address: 0008 0006h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	KEY[7:0]								—	—	—	—	—	—	—	ROME
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Bit	Symbol	Bit Name	Description	R/W
b0	ROME	On-Chip ROM Enable	0: The on-chip ROM is disabled 1: The on-chip ROM is enabled	R/W
b7 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b15 to b8	KEY[7:0]	SYSCR0 Key Code	5Ah: Modifying SYSCR0 is enabled Other codes: Modifying SYSCR0 is disabled These bits are always read as 00h.	R/W

SYSCR0 is used to enable or disable the on-chip ROM.

ROME Bit (On-Chip ROM Enable)

The ROME bit enables or disables the on-chip ROM (ROM, data flash).
While this bit is 1, it can be cleared to 0. While this bit is 0, it cannot be set to 1. Once the on-chip ROM is disabled by clearing this bit to 0, the on-chip ROM can no longer be enabled with the ROME bit. A 0 should not be written to this bit during access to the on-chip ROM.
After writing a 0 to this bit to disable the on-chip ROM, always make sure that the ROME bit has been changed to 0 before proceeding to the next processing.

KEY[7:0] Bits (SYSCR0 Key Code)

The KEY[7:0] bits enable or disable modifying SYSCR0.
When writing a value to the ROME bit, write 5Ah to the KEY[7:0] bits simultaneously. If SYSCR0 is modified with a KEY[7:0] value other than 5Ah, the ROME bit value remain unchanged.

3.2.4 System Control Register 1 (SYSCR1)

Address: 0008 0008h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	RAME
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Bit	Symbol	Bit Name	Description	R/W
b0	RAME	RAM Enable	0: The on-chip RAM is disabled 1: The on-chip RAM is enabled	R/W
b15 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

SYSCR1 is used to enable or disable the on-chip RAM.

RAME Bit (RAM Enable)

The RAME bit enables or disables the on-chip RAM.
The RAME bit is initialized to 1 after a reset is released.
A 0 should not be written to this bit during access to the on-chip RAM.
When accessing the on-chip RAM immediately after changing the RAME bit from 0 (on-chip RAM disabled) to 1 (on-chip RAM enabled), always make sure that the RAME bit is 1 before the access.
Even when the RAME bit is cleared to 0, the on-chip RAM retains its value.

3.3 Details of Operating Modes

3.3.1 Single-Chip Mode

In this mode, the on-chip ROM is enabled or disabled, the external bus is disabled, and all I/O ports can be used as input/output ports.
The on-chip ROM is enabled when this LSI is started. While the on-chip ROM is enabled (ROME bit = 1 in SYSCR0), it can be disabled by clearing the ROME bit in SYSCR0 to 0. While the on-chip ROM is disabled (ROME bit = 0 in SYSCR0), it cannot be enabled by setting the ROME bit in SYSCR0 to 1.

3.3.2 Boot Mode

Boot mode is provided for the flash memory. This mode functions in the same manner as single-chip mode except for data write/erase to the flash memory. For details, see section 31, ROM (Flash Memory for Code Storage), and section 32, Data Flash Memory (Flash Memory for Data Storage).

3.4 Transitions of Operating Modes

3.4.1 Operating Mode Transitions According to Mode Pin Setting

Figure 3.1shows operating mode transitions according to the setting of pins MD1 and MD0. Operating modes can shift in the direction of arrow.

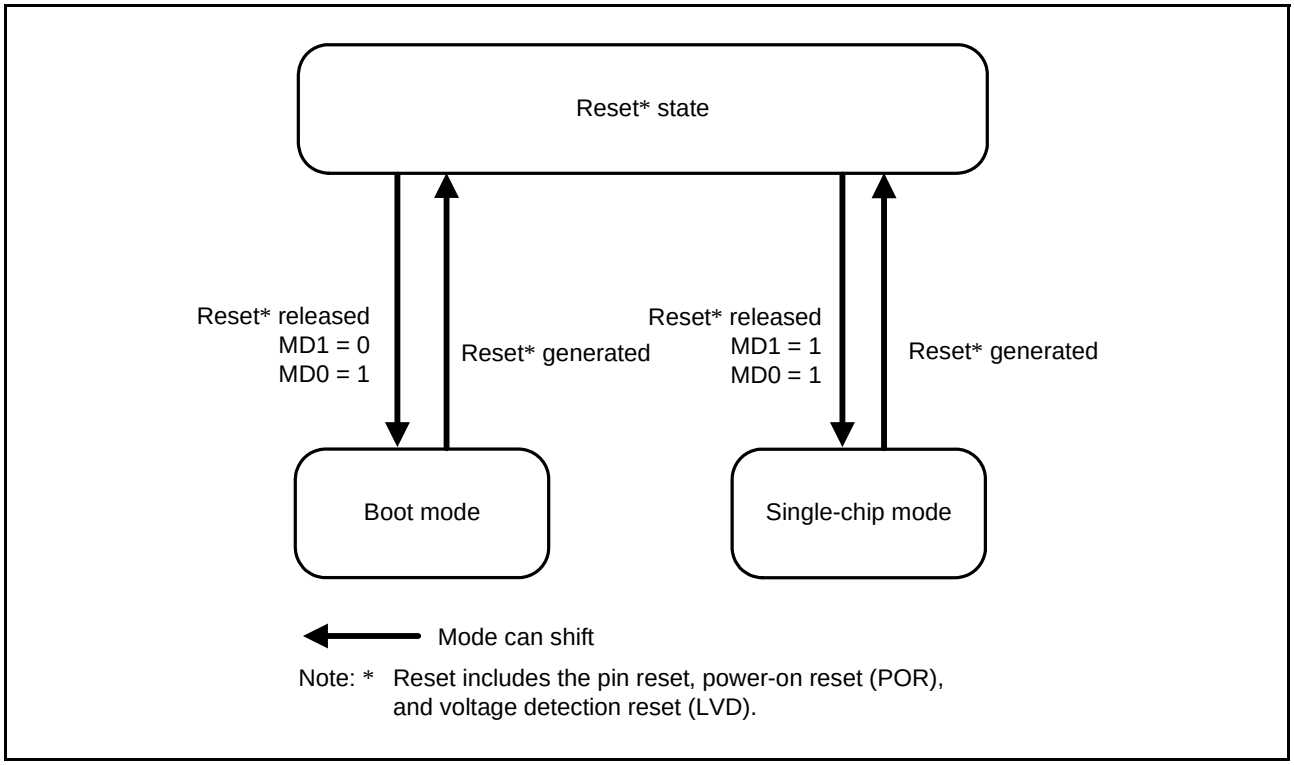


Figure 3.1 Setting of Pins MD1 and MD0 and Operating Modes

3.4.2 Operating Mode Transitions According to Register Setting

Figure 3.2 shows operating mode transitions according to the setting of the ROME and EXBE bits in SYSCR0. Operating modes can shift in the direction of arrow.

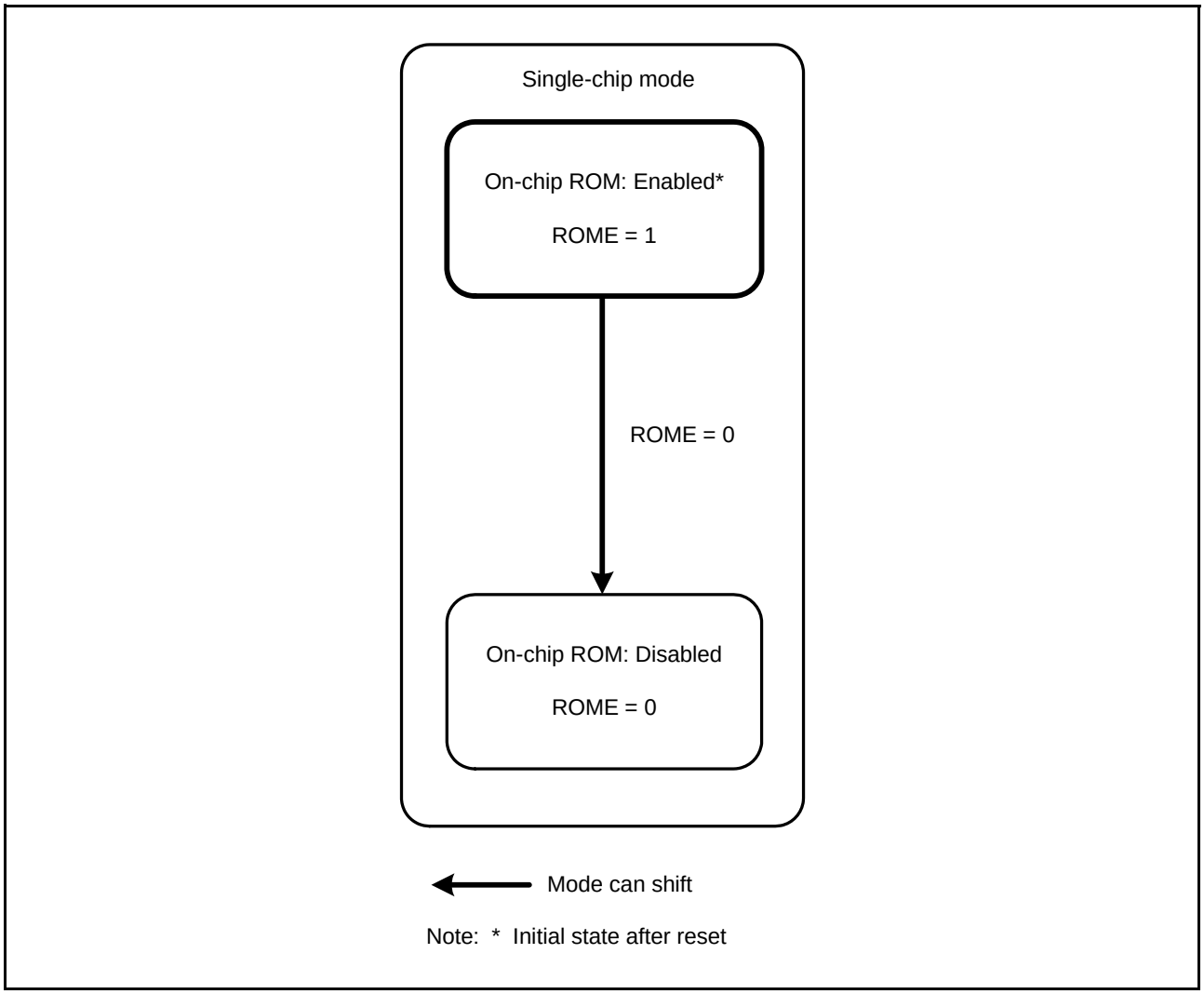
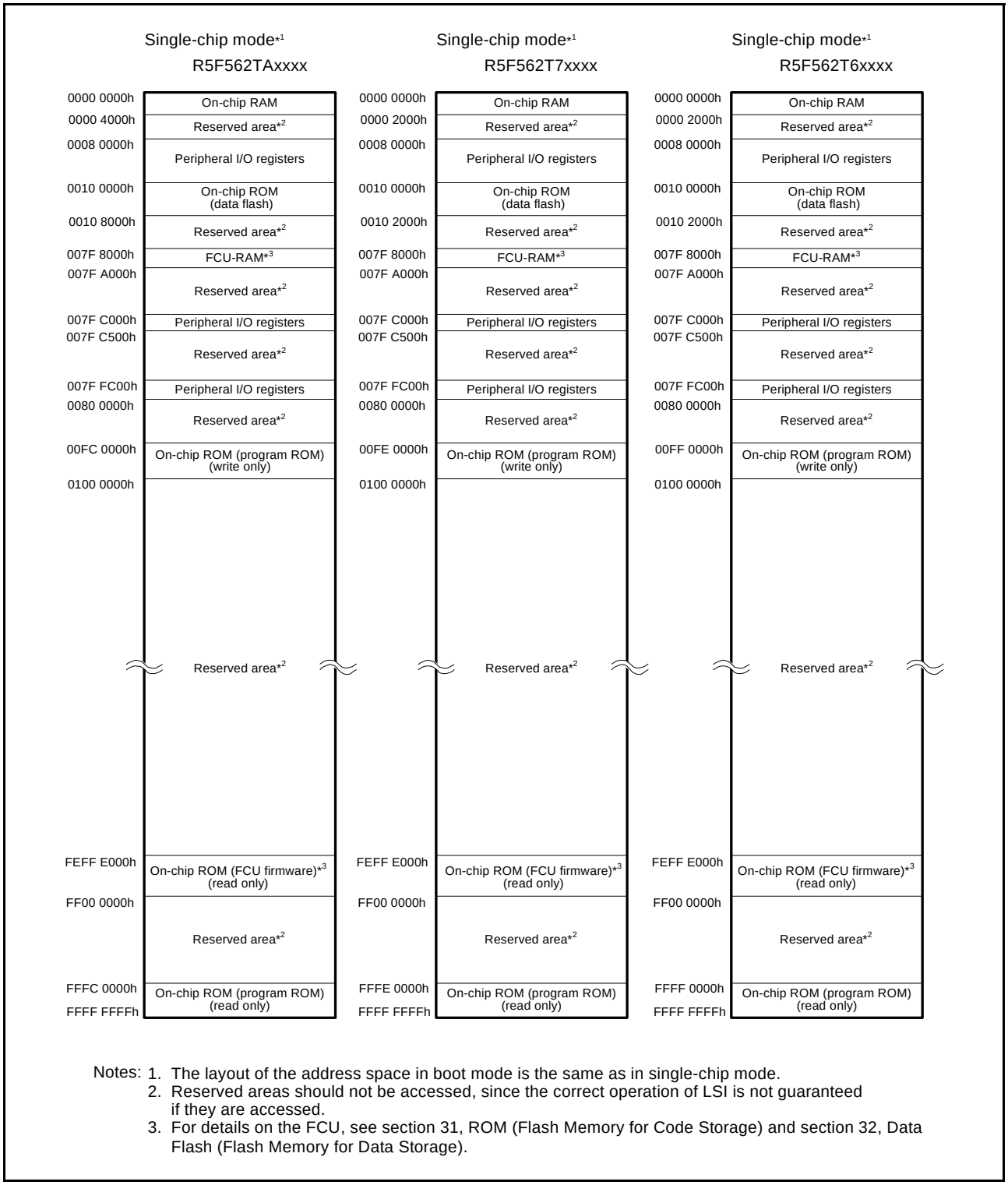


Figure 3.2 Setting of Bits ROME and Operating Modes

4. Address Space

4.1 Address Space

This LSI has a 4-Gbyte address space, consisting of the range of addresses from 0000 0000h to FFFF FFFFh. That is, linear access to an address space of up to 4 Gbytes is possible, and this contains both program and data areas. Figure 4.1 shows the memory maps.



Notes: 1. The layout of the address space in boot mode is the same as in single-chip mode.
2. Reserved areas should not be accessed, since the correct operation of LSI is not guaranteed if they are accessed.
3. For details on the FCU, see section 31, ROM (Flash Memory for Code Storage) and section 32, Data Flash (Flash Memory for Data Storage).

Figure 4.1 Memory Map (RX62T Group)

5. I/O Registers

This section gives information on the on-chip I/O register addresses and bit configurations. The information is given as shown below. Notes on writing to registers are also given at the end.

(1) I/O register addresses (address order)

- Registers are listed from the lower allocation addresses.
- Registers are classified according to functional modules (abbreviations).
- The number of access cycles indicates the number of states based on the specified reference clock.
- Among the I/O register area, addresses not listed in the list of registers are reserved. Reserved addresses must not be accessed. Do not access these addresses; otherwise, the operation when accessing these bits and subsequent operations cannot be guaranteed.
- A unit of access is specified for each register. Access other than in the specified unit is prohibited.

(2) I/O register bits

- Bit configurations of the registers are listed in the same order as the register addresses.
- Reserved bits are indicated by "—" in the bit name column.
- Space in the bit name field indicates that the entire register is allocated to either the counter or data.
- For the registers of 16 or 32 bits, the MSB is listed first.

(3) Notes on writing to I/O registers

When writing to an I/O register, the CPU starts executing the subsequent instruction before completing I/O register write. This may cause the subsequent instruction to be executed before the post-update I/O register value is reflected on the operation.
As described in the following examples, special care is required for the cases in which the subsequent instruction must be executed after the post-update I/O register value is actually reflected.

[Examples of cases requiring special care]

- The subsequent instruction must be executed while an interrupt request is disabled with the IENj bit in IERm of the ICU (interrupt request enable bit)*1 cleared to 0.
- A WAIT instruction is executed immediately after the preprocessing for causing a transition to the low power consumption state.

Note 1. See section 11.2.2, Interrupt Request Enable Register m (IERm) (m = 02h to 1Fh).

In the above cases, after writing to an I/O register, wait until the write operation is completed using the following procedure and then execute the subsequent instruction.

(a) Write to an I/O register.

(b) Read the value from the I/O register to a general register.

(c) Execute the operation using the value read.

(d) Execute the subsequent instruction.

[Instruction examples]

- Byte-size I/O registers

```
MOV.L  #SFR_ADDR, R1
MOV.B  #SFR_DATA, [R1]
CMP    [R1].UB, R1
;; Next process
```

- Word-size I/O registers

```
MOV.L  #SFR_ADDR, R1
MOV.W  #SFR_DATA, [R1]
CMP    [R1].W, R1
;; Next process
```

- Longword-size I/O registers

```
MOV.L  #SFR_ADDR, R1
MOV.L  #SFR_DATA, [R1]
CMP    [R1].L, R1
;; Next process
```

If multiple registers are written to and a subsequent instruction should be executed after the write operations are entirely completed, only read the I/O register that was last written to and execute the operation using the value; it is not necessary to read or execute operation for all the registers that were written to.

(4) Number of Access Cycles to I/O Registers

The number of access cycles to I/O registers is obtained by following equation.*

Number of access cycles to I/O registers = Number of bus cycles for internal main bus 1 +
Number of divided cycles for clock synchronization +
Number of bus cycles for internal peripheral buses 1, 2, 4, and 6

The number of bus cycles for internal peripheral buses 1, 2, 4, and 6 differs according to the register to be accessed. For the number of access cycles to each I/O register, see Table 5.1, List of I/O Registers.

When peripheral functions connected to internal peripheral bus 6 are accessed, the number of divided cycles for clock synchronization is added.

Although the number of divided cycles for clock synchronization differs depending on the number of frequency ratio between ICLK and PCLK or bus access timing, the sum of the number of bus cycles for internal main bus 1 and the number of divided cycles for clock synchronization will be one PCLK at a maximum. Therefore, one PCLK is added to the number of access cycles shown in Table 5.1.

Note: • This applies to the number of cycles when the access from the CPU does not conflict with the instruction fetching to the external memory or bus access from the different bus master (DTC).

5.1 I/O Register Addresses (Address Order)

Table 5.1 List of I/O Registers (Address Order) (1 / 24)

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 0000h	SYSTEM	Mode monitor register	MDMONR	16	16	3ICLK
0008 0002h	SYSTEM	Mode status register	MDSR	16	16	3ICLK
0008 0006h	SYSTEM	System control register 0	SYSCR0	16	16	3ICLK
0008 0008h	SYSTEM	System control register 1	SYSCR1	16	16	3ICLK
0008 000Ch	SYSTEM	Standby control register	SBYCR	16	16	3ICLK
0008 0010h	SYSTEM	Module stop control register A	MSTPCRA	32	32	3ICLK
0008 0014h	SYSTEM	Module stop control register B	MSTPCRB	32	32	3ICLK
0008 0018h	SYSTEM	Module stop control register C	MSTPCRC	32	32	3ICLK
0008 0020h	SYSTEM	System clock control register	SCKCR	32	32	3ICLK
0008 0040h	SYSTEM	Oscillation stop detection control register	OSTDCR	16	16	3ICLK
0008 1300h	BSC	Bus error status clear register	BERCLR	8	8	2ICLK
0008 1304h	BSC	Bus error monitoring enable register	BEREN	8	8	2ICLK
0008 1308h	BSC	Bus error status register 1	BERSR1	8	8	2ICLK
0008 130Ah	BSC	Bus error status register 2	BERSR2	16	16	2ICLK
0008 2400h	DTC	DTC control register	DTCCR	8	8	2ICLK
0008 2404h	DTC	DTC vector base register	DTCVBR	32	32	2ICLK
0008 2408h	DTC	DTC address mode register	DTCADMOD	8	8	2ICLK
0008 240Ch	DTC	DTC module start register	DTCST	8	8	2ICLK
0008 240Eh	DTC	DTC status register	DTCSTS	16	16	2ICLK
0008 6400h	MPU	Region 0 start page-number register	RSPAGE0	32	32	1ICLK
0008 6404h	MPU	Region 0 end page-number register	REPAGE0	32	32	1ICLK
0008 6408h	MPU	Region 1 start page-number register	RSPAGE1	32	32	1ICLK
0008 640Ch	MPU	Region 1 end page-number register	REPAGE1	32	32	1ICLK
0008 6410h	MPU	Region 2 start page-number register	RSPAGE2	32	32	1ICLK
0008 6414h	MPU	Region 2 end page-number register	REPAGE2	32	32	1ICLK
0008 6418h	MPU	Region 3 start page-number register	RSPAGE3	32	32	1ICLK
0008 641Ch	MPU	Region 3 end page-number register	REPAGE3	32	32	1ICLK
0008 6420h	MPU	Region 4 start page-number register	RSPAGE4	32	32	1ICLK
0008 6424h	MPU	Region 4 end page-number register	REPAGE4	32	32	1ICLK
0008 6428h	MPU	Region 5 start page-number register	RSPAGE5	32	32	1ICLK
0008 642Ch	MPU	Region 5 end page-number register	REPAGE5	32	32	1ICLK
0008 6430h	MPU	Region 6 start page-number register	RSPAGE6	32	32	1ICLK
0008 6434h	MPU	Region 6 end page-number register	REPAGE6	32	32	1ICLK
0008 6438h	MPU	Region 7 start page-number register	RSPAGE7	32	32	1ICLK
0008 643Ch	MPU	Region 7 end page-number register	REPAGE7	32	32	1ICLK
0008 6500h	MPU	Memory-protection enable register	MPEN	32	32	1ICLK
0008 6504h	MPU	Background access control register	MPBAC	32	32	1ICLK
0008 6508h	MPU	Memory-protection error status-clearing register	MPECLR	32	32	1ICLK
0008 650Ch	MPU	Memory-protection error status register	MPESTS	32	32	1ICLK
0008 6514h	MPU	Data memory-protection error address register	MPDEA	32	32	1ICLK
0008 6520h	MPU	Region search address register	MPSA	32	32	1ICLK
0008 6524h	MPU	Region search operation register	MPOPS	16	16	1ICLK

Table 5.1 List of I/O Registers (Address Order) (2 / 24)

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 6526h	MPU	Region invalidation operation register	MPOPI	16	16	1ICLK
0008 6528h	MPU	Instruction-hit region register	MHITI	32	32	1ICLK
0008 652Ch	MPU	Data-hit region register	MHITD	32	32	1ICLK
0008 7010h	ICU	Interrupt request register 016	IR016	8	8	2ICLK
0008 7015h	ICU	Interrupt request register 021	IR021	8	8	2ICLK
0008 7017h	ICU	Interrupt request register 023	IR023	8	8	2ICLK
0008 701Bh	ICU	Interrupt request register 027	IR027	8	8	2ICLK
0008 701Ch	ICU	Interrupt request register 028	IR028	8	8	2ICLK
0008 701Dh	ICU	Interrupt request register 029	IR029	8	8	2ICLK
0008 701Eh	ICU	Interrupt request register 030	IR030	8	8	2ICLK
0008 701Fh	ICU	Interrupt request register 031	IR031	8	8	2ICLK
0008 702Ch	ICU	Interrupt request register 044	IR044	8	8	2ICLK
0008 702Dh	ICU	Interrupt request register 045	IR045	8	8	2ICLK
0008 702Eh	ICU	Interrupt request register 046	IR046	8	8	2ICLK
0008 702Fh	ICU	Interrupt request register 047	IR047	8	8	2ICLK
0008 7038h	ICU	Interrupt request register 056	IR056	8	8	2ICLK
0008 7039h	ICU	Interrupt request register 057	IR057	8	8	2ICLK
0008 703Ah	ICU	Interrupt request register 058	IR058	8	8	2ICLK
0008 703Bh	ICU	Interrupt request register 059	IR059	8	8	2ICLK
0008 703Ch	ICU	Interrupt request register 060	IR060	8	8	2ICLK
0008 7040h	ICU	Interrupt request register 064	IR064	8	8	2ICLK
0008 7041h	ICU	Interrupt request register 065	IR065	8	8	2ICLK
0008 7042h	ICU	Interrupt request register 066	IR066	8	8	2ICLK
0008 7043h	ICU	Interrupt request register 067	IR067	8	8	2ICLK
0008 7044h	ICU	Interrupt request register 068	IR068	8	8	2ICLK
0008 7045h	ICU	Interrupt request register 069	IR069	8	8	2ICLK
0008 7046h	ICU	Interrupt request register 070	IR070	8	8	2ICLK
0008 7047h	ICU	Interrupt request register 071	IR071	8	8	2ICLK
0008 7060h	ICU	Interrupt request register 096	IR096	8	8	2ICLK
0008 7062h	ICU	Interrupt request register 098	IR098	8	8	2ICLK
0008 7066h	ICU	Interrupt request register 102	IR102	8	8	2ICLK
0008 7067h	ICU	Interrupt request register 103	IR103	8	8	2ICLK
0008 706Ah	ICU	Interrupt request register 106	IR106	8	8	2ICLK
0008 7072h	ICU	Interrupt request register 114	IR114	8	8	2ICLK
0008 7073h	ICU	Interrupt request register 115	IR115	8	8	2ICLK
0008 7074h	ICU	Interrupt request register 116	IR116	8	8	2ICLK
0008 7075h	ICU	Interrupt request register 117	IR117	8	8	2ICLK
0008 7076h	ICU	Interrupt request register 118	IR118	8	8	2ICLK
0008 7077h	ICU	Interrupt request register 119	IR119	8	8	2ICLK
0008 7078h	ICU	Interrupt request register 120	IR120	8	8	2ICLK
0008 7079h	ICU	Interrupt request register 121	IR121	8	8	2ICLK
0008 707Ah	ICU	Interrupt request register 122	IR122	8	8	2ICLK
0008 707Bh	ICU	Interrupt request register 123	IR123	8	8	2ICLK
0008 707Ch	ICU	Interrupt request register 124	IR124	8	8	2ICLK

Table 5.1 List of I/O Registers (Address Order) (3 / 24)

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 707Dh	ICU	Interrupt request register 125	IR125	8	8	2ICLK
0008 707Eh	ICU	Interrupt request register 126	IR126	8	8	2ICLK
0008 707Fh	ICU	Interrupt request register 127	IR127	8	8	2ICLK
0008 7080h	ICU	Interrupt request register 128	IR128	8	8	2ICLK
0008 7081h	ICU	Interrupt request register 129	IR129	8	8	2ICLK
0008 7082h	ICU	Interrupt request register 130	IR130	8	8	2ICLK
0008 7083h	ICU	Interrupt request register 131	IR131	8	8	2ICLK
0008 7084h	ICU	Interrupt request register 132	IR132	8	8	2ICLK
0008 7085h	ICU	Interrupt request register 133	IR133	8	8	2ICLK
0008 7086h	ICU	Interrupt request register 134	IR134	8	8	2ICLK
0008 7087h	ICU	Interrupt request register 135	IR135	8	8	2ICLK
0008 7088h	ICU	Interrupt request register 136	IR136	8	8	2ICLK
0008 7089h	ICU	Interrupt request register 137	IR137	8	8	2ICLK
0008 708Ah	ICU	Interrupt request register 138	IR138	8	8	2ICLK
0008 708Bh	ICU	Interrupt request register 139	IR139	8	8	2ICLK
0008 708Ch	ICU	Interrupt request register 140	IR140	8	8	2ICLK
0008 708Dh	ICU	Interrupt request register 141	IR141	8	8	2ICLK
0008 708Eh	ICU	Interrupt request register 142	IR142	8	8	2ICLK
0008 708Fh	ICU	Interrupt request register 143	IR143	8	8	2ICLK
0008 7090h	ICU	Interrupt request register 144	IR144	8	8	2ICLK
0008 7091h	ICU	Interrupt request register 145	IR145	8	8	2ICLK
0008 7092h	ICU	Interrupt request register 146	IR146	8	8	2ICLK
0008 7095h	ICU	Interrupt request register 149	IR149	8	8	2ICLK
0008 7096h	ICU	Interrupt request register 150	IR150	8	8	2ICLK
0008 7097h	ICU	Interrupt request register 151	IR151	8	8	2ICLK
0008 7098h	ICU	Interrupt request register 152	IR152	8	8	2ICLK
0008 7099h	ICU	Interrupt request register 153	IR153	8	8	2ICLK
0008 70AAh	ICU	Interrupt request register 170	IR170	8	8	2ICLK
0008 70ABh	ICU	Interrupt request register 171	IR171	8	8	2ICLK
0008 70ACh	ICU	Interrupt request register 172	IR172	8	8	2ICLK
0008 70ADh	ICU	Interrupt request register 173	IR173	8	8	2ICLK
0008 70AEh	ICU	Interrupt request register 174	IR174	8	8	2ICLK
0008 70AFh	ICU	Interrupt request register 175	IR175	8	8	2ICLK
0008 70B0h	ICU	Interrupt request register 176	IR176	8	8	2ICLK
0008 70B1h	ICU	Interrupt request register 177	IR177	8	8	2ICLK
0008 70B2h	ICU	Interrupt request register 178	IR178	8	8	2ICLK
0008 70B3h	ICU	Interrupt request register 179	IR179	8	8	2ICLK
0008 70B4h	ICU	Interrupt request register 180	IR180	8	8	2ICLK
0008 70B5h	ICU	Interrupt request register 181	IR181	8	8	2ICLK
0008 70B6h	ICU	Interrupt request register 182	IR182	8	8	2ICLK
0008 70B7h	ICU	Interrupt request register 183	IR183	8	8	2ICLK
0008 70B8h	ICU	Interrupt request register 184	IR184	8	8	2ICLK
0008 70BAh	ICU	Interrupt request register 186	IR186	8	8	2ICLK
0008 70BBh	ICU	Interrupt request register 187	IR187	8	8	2ICLK

Table 5.1 List of I/O Registers (Address Order) (4 / 24)

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 70BCh	ICU	Interrupt request register 188	IR188	8	8	2ICLK
0008 70BDh	ICU	Interrupt request register 189	IR189	8	8	2ICLK
0008 70BEh	ICU	Interrupt request register 190	IR190	8	8	2ICLK
0008 70C0h	ICU	Interrupt request register 192	IR192	8	8	2ICLK
0008 70C1h	ICU	Interrupt request register 193	IR193	8	8	2ICLK
0008 70C2h	ICU	Interrupt request register 194	IR194	8	8	2ICLK
0008 70C3h	ICU	Interrupt request register 195	IR195	8	8	2ICLK
0008 70C4h	ICU	Interrupt request register 196	IR196	8	8	2ICLK
0008 70D6h	ICU	Interrupt request register 214	IR214	8	8	2ICLK
0008 70D7h	ICU	Interrupt request register 215	IR215	8	8	2ICLK
0008 70D8h	ICU	Interrupt request register 216	IR216	8	8	2ICLK
0008 70D9h	ICU	Interrupt request register 217	IR217	8	8	2ICLK
0008 70DAh	ICU	Interrupt request register 218	IR218	8	8	2ICLK
0008 70DBh	ICU	Interrupt request register 219	IR219	8	8	2ICLK
0008 70DCh	ICU	Interrupt request register 220	IR220	8	8	2ICLK
0008 70DDh	ICU	Interrupt request register 221	IR221	8	8	2ICLK
0008 70DEh	ICU	Interrupt request register 222	IR222	8	8	2ICLK
0008 70DFh	ICU	Interrupt request register 223	IR223	8	8	2ICLK
0008 70E0h	ICU	Interrupt request register 224	IR224	8	8	2ICLK
0008 70E1h	ICU	Interrupt request register 225	IR225	8	8	2ICLK
0008 70F6h	ICU	Interrupt request register 246	IR246	8	8	2ICLK
0008 70F7h	ICU	Interrupt request register 247	IR247	8	8	2ICLK
0008 70F8h	ICU	Interrupt request register 248	IR248	8	8	2ICLK
0008 70F9h	ICU	Interrupt request register 249	IR249	8	8	2ICLK
0008 70FEh	ICU	Interrupt request register 254	IR254	8	8	2ICLK
0008 711Bh	ICU	DTC activation enable register 027	DTCER027	8	8	2ICLK
0008 711Ch	ICU	DTC activation enable register 028	DTCER028	8	8	2ICLK
0008 711Dh	ICU	DTC activation enable register 029	DTCER029	8	8	2ICLK
0008 711Eh	ICU	DTC activation enable register 030	DTCER030	8	8	2ICLK
0008 711Fh	ICU	DTC activation enable register 031	DTCER031	8	8	2ICLK
0008 712Dh	ICU	DTC activation enable register 045	DTCER045	8	8	2ICLK
0008 712Eh	ICU	DTC activation enable register 046	DTCER046	8	8	2ICLK
0008 7140h	ICU	DTC activation enable register 064	DTCER064	8	8	2ICLK
0008 7141h	ICU	DTC activation enable register 065	DTCER065	8	8	2ICLK
0008 7142h	ICU	DTC activation enable register 066	DTCER066	8	8	2ICLK
0008 7143h	ICU	DTC activation enable register 067	DTCER067	8	8	2ICLK
0008 7144h	ICU	DTC activation enable register 068	DTCER068	8	8	2ICLK
0008 7145h	ICU	DTC activation enable register 069	DTCER069	8	8	2ICLK
0008 7146h	ICU	DTC activation enable register 070	DTCER070	8	8	2ICLK
0008 7147h	ICU	DTC activation enable register 071	DTCER071	8	8	2ICLK
0008 7162h	ICU	DTC activation enable register 098	DTCER098	8	8	2ICLK
0008 7166h	ICU	DTC activation enable register 102	DTCER102	8	8	2ICLK
0008 7167h	ICU	DTC activation enable register 103	DTCER103	8	8	2ICLK
0008 716Ah	ICU	DTC activation enable register 106	DTCER106	8	8	2ICLK

Table 5.1 List of I/O Registers (Address Order) (5 / 24)

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 7172h	ICU	DTC activation enable register 114	DTCER114	8	8	2ICLK
0008 7173h	ICU	DTC activation enable register 115	DTCER115	8	8	2ICLK
0008 7174h	ICU	DTC activation enable register 116	DTCER116	8	8	2ICLK
0008 7175h	ICU	DTC activation enable register 117	DTCER117	8	8	2ICLK
0008 7179h	ICU	DTC activation enable register 121	DTCER121	8	8	2ICLK
0008 717Ah	ICU	DTC activation enable register 122	DTCER122	8	8	2ICLK
0008 717Dh	ICU	DTC activation enable register 125	DTCER125	8	8	2ICLK
0008 717Eh	ICU	DTC activation enable register 126	DTCER126	8	8	2ICLK
0008 7181h	ICU	DTC activation enable register 129	DTCER129	8	8	2ICLK
0008 7182h	ICU	DTC activation enable register 130	DTCER130	8	8	2ICLK
0008 7183h	ICU	DTC activation enable register 131	DTCER131	8	8	2ICLK
0008 7184h	ICU	DTC activation enable register 132	DTCER132	8	8	2ICLK
0008 7186h	ICU	DTC activation enable register 134	DTCER134	8	8	2ICLK
0008 7187h	ICU	DTC activation enable register 135	DTCER135	8	8	2ICLK
0008 7188h	ICU	DTC activation enable register 136	DTCER136	8	8	2ICLK
0008 7189h	ICU	DTC activation enable register 137	DTCER137	8	8	2ICLK
0008 718Ah	ICU	DTC activation enable register 138	DTCER138	8	8	2ICLK
0008 718Bh	ICU	DTC activation enable register 139	DTCER139	8	8	2ICLK
0008 718Ch	ICU	DTC activation enable register 140	DTCER140	8	8	2ICLK
0008 718Dh	ICU	DTC activation enable register 141	DTCER141	8	8	2ICLK
0008 718Eh	ICU	DTC activation enable register 142	DTCER142	8	8	2ICLK
0008 718Fh	ICU	DTC activation enable register 143	DTCER143	8	8	2ICLK
0008 7190h	ICU	DTC activation enable register 144	DTCER144	8	8	2ICLK
0008 7191h	ICU	DTC activation enable register 145	DTCER145	8	8	2ICLK
0008 7195h	ICU	DTC activation enable register 149	DTCER149	8	8	2ICLK
0008 7196h	ICU	DTC activation enable register 150	DTCER150	8	8	2ICLK
0008 7197h	ICU	DTC activation enable register 151	DTCER151	8	8	2ICLK
0008 7198h	ICU	DTC activation enable register 152	DTCER152	8	8	2ICLK
0008 7199h	ICU	DTC activation enable register 153	DTCER153	8	8	2ICLK
0008 71AEh	ICU	DTC activation enable register 174	DTCER174	8	8	2ICLK
0008 71AFh	ICU	DTC activation enable register 175	DTCER175	8	8	2ICLK
0008 71B0h	ICU	DTC activation enable register 176	DTCER176	8	8	2ICLK
0008 71B1h	ICU	DTC activation enable register 177	DTCER177	8	8	2ICLK
0008 71B2h	ICU	DTC activation enable register 178	DTCER178	8	8	2ICLK
0008 71B3h	ICU	DTC activation enable register 179	DTCER179	8	8	2ICLK
0008 71B4h	ICU	DTC activation enable register 180	DTCER180	8	8	2ICLK
0008 71B5h	ICU	DTC activation enable register 181	DTCER181	8	8	2ICLK
0008 71B6h	ICU	DTC activation enable register 182	DTCER182	8	8	2ICLK
0008 71B7h	ICU	DTC activation enable register 183	DTCER183	8	8	2ICLK
0008 71B8h	ICU	DTC activation enable register 184	DTCER184	8	8	2ICLK
0008 71BAh	ICU	DTC activation enable register 186	DTCER186	8	8	2ICLK
0008 71BBh	ICU	DTC activation enable register 187	DTCER187	8	8	2ICLK
0008 71BCh	ICU	DTC activation enable register 188	DTCER188	8	8	2ICLK
0008 71BDh	ICU	DTC activation enable register 189	DTCER189	8	8	2ICLK

Table 5.1 List of I/O Registers (Address Order) (6 / 24)

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 71BEh	ICU	DTC activation enable register 190	DTCER190	8	8	2ICLK
0008 71C0h	ICU	DTC activation enable register 192	DTCER192	8	8	2ICLK
0008 71C1h	ICU	DTC activation enable register 193	DTCER193	8	8	2ICLK
0008 71C2h	ICU	DTC activation enable register 194	DTCER194	8	8	2ICLK
0008 71C3h	ICU	DTC activation enable register 195	DTCER195	8	8	2ICLK
0008 71C4h	ICU	DTC activation enable register 196	DTCER196	8	8	2ICLK
0008 71D7h	ICU	DTC activation enable register 215	DTCER215	8	8	2ICLK
0008 71D8h	ICU	DTC activation enable register 216	DTCER216	8	8	2ICLK
0008 71DBh	ICU	DTC activation enable register 219	DTCER219	8	8	2ICLK
0008 71DCh	ICU	DTC activation enable register 220	DTCER220	8	8	2ICLK
0008 71DFh	ICU	DTC activation enable register 223	DTCER223	8	8	2ICLK
0008 71E0h	ICU	DTC activation enable register 224	DTCER224	8	8	2ICLK
0008 71F7h	ICU	DTC activation enable register 247	DTCER247	8	8	2ICLK
0008 71F8h	ICU	DTC activation enable register 248	DTCER248	8	8	2ICLK
0008 71FEh	ICU	DTC activation enable register 254	DTCER254	8	8	2ICLK
0008 7202h	ICU	Interrupt request enable register 02	IER02	8	8	2ICLK
0008 7203h	ICU	Interrupt request enable register 03	IER03	8	8	2ICLK
0008 7205h	ICU	Interrupt request enable register 05	IER05	8	8	2ICLK
0008 7207h	ICU	Interrupt request enable register 07	IER07	8	8	2ICLK
0008 7208h	ICU	Interrupt request enable register 08	IER08	8	8	2ICLK
0008 720Ch	ICU	Interrupt request enable register 0C	IER0C	8	8	2ICLK
0008 720Dh	ICU	Interrupt request enable register 0D	IER0D	8	8	2ICLK
0008 720Eh	ICU	Interrupt request enable register 0E	IER0E	8	8	2ICLK
0008 720Fh	ICU	Interrupt request enable register 0F	IER0F	8	8	2ICLK
0008 7210h	ICU	Interrupt request enable register 10	IER10	8	8	2ICLK
0008 7211h	ICU	Interrupt request enable register 11	IER11	8	8	2ICLK
0008 7212h	ICU	Interrupt request enable register 12	IER12	8	8	2ICLK
0008 7213h	ICU	Interrupt request enable register 13	IER13	8	8	2ICLK
0008 7215h	ICU	Interrupt request enable register 15	IER15	8	8	2ICLK
0008 7216h	ICU	Interrupt request enable register 16	IER16	8	8	2ICLK
0008 7217h	ICU	Interrupt request enable register 17	IER17	8	8	2ICLK
0008 7218h	ICU	Interrupt request enable register 18	IER18	8	8	2ICLK
0008 721Ah	ICU	Interrupt request enable register 1A	IER1A	8	8	2ICLK
0008 721Bh	ICU	Interrupt request enable register 1B	IER1B	8	8	2ICLK
0008 721Ch	ICU	Interrupt request enable register 1C	IER1C	8	8	2ICLK
0008 721Eh	ICU	Interrupt request enable register 1E	IER1E	8	8	2ICLK
0008 721Fh	ICU	Interrupt request enable register 1F	IER1F	8	8	2ICLK
0008 72E0h	ICU	Software interrupt activation register	SWINTR	8	8	2ICLK
0008 72F0h	ICU	Fast interrupt set register	FIR	16	16	2ICLK
0008 7300h	ICU	Interrupt source priority register 00	IPR00	8	8	2ICLK
0008 7301h	ICU	Interrupt source priority register 01	IPR01	8	8	2ICLK
0008 7302h	ICU	Interrupt source priority register 02	IPR02	8	8	2ICLK
0008 7303h	ICU	Interrupt source priority register 03	IPR03	8	8	2ICLK
0008 7304h	ICU	Interrupt source priority register 04	IPR04	8	8	2ICLK

Table 5.1 List of I/O Registers (Address Order) (7 / 24)

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 7305h	ICU	Interrupt source priority register 05	IPR05	8	8	2ICLK
0008 7306h	ICU	Interrupt source priority register 06	IPR06	8	8	2ICLK
0008 7307h	ICU	Interrupt source priority register 07	IPR07	8	8	2ICLK
0008 7314h	ICU	Interrupt source priority register 14	IPR14	8	8	2ICLK
0008 7318h	ICU	Interrupt source priority register 18	IPR18	8	8	2ICLK
0008 7320h	ICU	Interrupt source priority register 20	IPR20	8	8	2ICLK
0008 7321h	ICU	Interrupt source priority register 21	IPR21	8	8	2ICLK
0008 7322h	ICU	Interrupt source priority register 22	IPR22	8	8	2ICLK
0008 7323h	ICU	Interrupt source priority register 23	IPR23	8	8	2ICLK
0008 7324h	ICU	Interrupt source priority register 24	IPR24	8	8	2ICLK
0008 7325h	ICU	Interrupt source priority register 25	IPR25	8	8	2ICLK
0008 7326h	ICU	Interrupt source priority register 26	IPR26	8	8	2ICLK
0008 7327h	ICU	Interrupt source priority register 27	IPR27	8	8	2ICLK
0008 7340h	ICU	Interrupt source priority register 40	IPR40	8	8	2ICLK
0008 7344h	ICU	Interrupt source priority register 44	IPR44	8	8	2ICLK
0008 7348h	ICU	Interrupt source priority register 48	IPR48	8	8	2ICLK
0008 7349h	ICU	Interrupt source priority register 49	IPR49	8	8	2ICLK
0008 7351h	ICU	Interrupt source priority register 51	IPR51	8	8	2ICLK
0008 7352h	ICU	Interrupt source priority register 52	IPR52	8	8	2ICLK
0008 7353h	ICU	Interrupt source priority register 53	IPR53	8	8	2ICLK
0008 7354h	ICU	Interrupt source priority register 54	IPR54	8	8	2ICLK
0008 7355h	ICU	Interrupt source priority register 55	IPR55	8	8	2ICLK
0008 7356h	ICU	Interrupt source priority register 56	IPR56	8	8	2ICLK
0008 7357h	ICU	Interrupt source priority register 57	IPR57	8	8	2ICLK
0008 7358h	ICU	Interrupt source priority register 58	IPR58	8	8	2ICLK
0008 7359h	ICU	Interrupt source priority register 59	IPR59	8	8	2ICLK
0008 735Ah	ICU	Interrupt source priority register 5A	IPR5A	8	8	2ICLK
0008 735Bh	ICU	Interrupt source priority register 5B	IPR5B	8	8	2ICLK
0008 735Ch	ICU	Interrupt source priority register 5C	IPR5C	8	8	2ICLK
0008 735Dh	ICU	Interrupt source priority register 5D	IPR5D	8	8	2ICLK
0008 735Eh	ICU	Interrupt source priority register 5E	IPR5E	8	8	2ICLK
0008 735Fh	ICU	Interrupt source priority register 5F	IPR5F	8	8	2ICLK
0008 7360h	ICU	Interrupt source priority register 60	IPR60	8	8	2ICLK
0008 7367h	ICU	Interrupt source priority register 67	IPR67	8	8	2ICLK
0008 7368h	ICU	Interrupt source priority register 68	IPR68	8	8	2ICLK
0008 7369h	ICU	Interrupt source priority register 69	IPR69	8	8	2ICLK
0008 736Ah	ICU	Interrupt source priority register 6A	IPR6A	8	8	2ICLK
0008 736Bh	ICU	Interrupt source priority register 6B	IPR6B	8	8	2ICLK
0008 736Ch	ICU	Interrupt source priority register 6C	IPR6C	8	8	2ICLK
0008 736Dh	ICU	Interrupt source priority register 6D	IPR6D	8	8	2ICLK
0008 736Eh	ICU	Interrupt source priority register 6E	IPR6E	8	8	2ICLK
0008 736Fh	ICU	Interrupt source priority register 6F	IPR6F	8	8	2ICLK
0008 7380h	ICU	Interrupt source priority register 80	IPR80	8	8	2ICLK
0008 7381h	ICU	Interrupt source priority register 81	IPR81	8	8	2ICLK

Table 5.1 List of I/O Registers (Address Order) (8 / 24)

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 7382h	ICU	Interrupt source priority register 82	IPR82	8	8	2ICLK
0008 7388h	ICU	Interrupt source priority register 88	IPR88	8	8	2ICLK
0008 7389h	ICU	Interrupt source priority register 89	IPR89	8	8	2ICLK
0008 738Ah	ICU	Interrupt source priority register 8A	IPR8A	8	8	2ICLK
0008 738Bh	ICU	Interrupt source priority register 8B	IPR8B	8	8	2ICLK
0008 7390h	ICU	Interrupt source priority register 90	IPR90	8	8	2ICLK
0008 7500h	ICU	IRQ control register 0	IRQCR0	8	8	2ICLK
0008 7501h	ICU	IRQ control register 1	IRQCR1	8	8	2ICLK
0008 7502h	ICU	IRQ control register 2	IRQCR2	8	8	2ICLK
0008 7503h	ICU	IRQ control register 3	IRQCR3	8	8	2ICLK
0008 7504h	ICU	IRQ control register 4	IRQCR4	8	8	2ICLK
0008 7505h	ICU	IRQ control register 5	IRQCR5	8	8	2ICLK
0008 7506h	ICU	IRQ control register 6	IRQCR6	8	8	2ICLK
0008 7507h	ICU	IRQ control register 7	IRQCR7	8	8	2ICLK
0008 7580h	ICU	Non-maskable interrupt status register	NMISR	8	8	2ICLK
0008 7581h	ICU	Non-maskable interrupt enable register	NMIER	8	8	2ICLK
0008 7582h	ICU	Non-maskable interrupt clear register	NMICLR	8	8	2ICLK
0008 7583h	ICU	NMI pin interrupt control register	NMICR	8	8	2ICLK
0008 8000h	CMT	Compare match timer start register 0	CMSTR0	16	16	2 to 3PCLK*5
0008 8002h	CMT0	Compare match timer control register	CMCR	16	16	2 to 3PCLK*5
0008 8004h	CMT0	Compare match timer counter	CMCNT	16	16	2 to 3PCLK*5
0008 8006h	CMT0	Compare match timer constant register	CMCOR	16	16	2 to 3PCLK*5
0008 8008h	CMT1	Compare match timer control register	CMCR	16	16	2 to 3PCLK*5
0008 800Ah	CMT1	Compare match timer counter	CMCNT	16	16	2 to 3PCLK*5
0008 800Ch	CMT1	Compare match timer constant register	CMCOR	16	16	2 to 3PCLK*5
0008 8010h	CMT	Compare match timer start register 1	CMSTR1	16	16	2 to 3PCLK*5
0008 8012h	CMT2	Compare match timer control register	CMCR	16	16	2 to 3PCLK*5
0008 8014h	CMT2	Compare match timer counter	CMCNT	16	16	2 to 3PCLK*5
0008 8016h	CMT2	Compare match timer constant register	CMCOR	16	16	2 to 3PCLK*5
0008 8018h	CMT3	Compare match timer control register	CMCR	16	16	2 to 3PCLK*5
0008 801Ah	CMT3	Compare match timer counter	CMCNT	16	16	2 to 3PCLK*5
0008 801Ch	CMT3	Compare match timer constant register	CMCOR	16	16	2 to 3PCLK*5
0008 8028h	WDT	Timer control/status register	TCSR	8	8	2 to 3PCLK*5
0008 8028h	WDT	Write window A register	WINA	16	16	2 to 3PCLK*5
0008 8029h	WDT	Timer counter	TCNT	8	8	2 to 3PCLK*5
0008 802Ah	WDT	Write window B register	WINB	16	16	2 to 3PCLK*5
0008 802Bh	WDT	Reset control/status register	RSTCSR	8	8	2 to 3PCLK*5
0008 8030h	IWDT	IWDT refresh register	IWDTRR	8	8	2 to 3PCLK*5
0008 8032h	IWDT	IWDT control register	IWDTCR	16	16	2 to 3PCLK*5
0008 8034h	IWDT	IWDT status register	IWDTSR	16	16	2 to 3PCLK*5
0008 8040h	ADA	A/D data register A	ADDRA	16	16	2 to 3PCLK*5
0008 8042h	ADA	A/D data register B	ADDRB	16	16	2 to 3PCLK*5
0008 8044h	ADA	A/D data register C	ADDRC	16	16	2 to 3PCLK*5
0008 8046h	ADA	A/D data register D	ADDRD	16	16	2 to 3PCLK*5

Table 5.1 List of I/O Registers (Address Order) (9 / 24)

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 8048h	ADA	A/D data register E	ADDRE	16	16	2 to 3PCLK*5
0008 804Ah	ADA	A/D data register F	ADDRF	16	16	2 to 3PCLK*5
0008 804Ch	ADA	A/D data register G	ADDRG	16	16	2 to 3PCLK*5
0008 804Eh	ADA	A/D data register H	ADDRH	16	16	2 to 3PCLK*5
0008 8050h	ADA	A/D control/status register	ADCSR	8	8	2 to 3PCLK*5
0008 8051h	ADA	A/D control register	ADCR	8	8	2 to 3PCLK*5
0008 805Bh	ADA	A/D sampling state register	ADSSTR	8	8	2 to 3PCLK*5
0008 805Dh	ADA	A/D self-diagnostic register	ADDIAGR	8	8	2 to 3PCLK*5
0008 8060h	ADA	A/D data register I	ADDRI	16	16	2 to 3PCLK*5
0008 8062h	ADA	A/D data register J	ADDRJ	16	16	2 to 3PCLK*5
0008 8064h	ADA	A/D data register K	ADDRK	16	16	2 to 3PCLK*5
0008 8066h	ADA	A/D data register L	ADDRL	16	16	2 to 3PCLK*5
0008 8070h	ADA	A/D start trigger select register	ADSTRGR	8	8	2 to 3PCLK*5
0008 8072h	ADA	A/D data placement register	ADDPR	8	8	2 to 3PCLK*5
0008 8240h	SCI0	Serial mode register	SMR*1	8	8	2 to 3PCLK*5
0008 8241h	SCI0	Bit rate register	BRR	8	8	2 to 3PCLK*5
0008 8242h	SCI0	Serial control register	SCR*1	8	8	2 to 3PCLK*5
0008 8243h	SCI0	Transmit data register	TDR	8	8	2 to 3PCLK*5
0008 8244h	SCI0	Serial status register	SSR*1	8	8	2 to 3PCLK*5
0008 8245h	SCI0	Receive data register	RDR	8	8	2 to 3PCLK*5
0008 8246h	SCI0	Smart card mode register	SCMR	8	8	2 to 3PCLK*5
0008 8247h	SCI0	Serial extended mode register	SEMR	8	8	2 to 3PCLK*5
0008 8240h	SMCI0	Serial mode register	SMR	8	8	2 to 3PCLK*5
0008 8241h	SMCI0	Bit rate register	BRR	8	8	2 to 3PCLK*5
0008 8242h	SMCI0	Serial control register	SCR	8	8	2 to 3PCLK*5
0008 8243h	SMCI0	Transmit data register	TDR	8	8	2 to 3PCLK*5
0008 8244h	SMCI0	Serial status register	SSR	8	8	2 to 3PCLK*5
0008 8245h	SMCI0	Receive data register	RDR	8	8	2 to 3PCLK*5
0008 8246h	SMCI0	Smart card mode register	SCMR	8	8	2 to 3PCLK*5
0008 8248h	SCI1	Serial mode register	SMR*1	8	8	2 to 3PCLK*5
0008 8249h	SCI1	Bit rate register	BRR	8	8	2 to 3PCLK*5
0008 824Ah	SCI1	Serial control register	SCR*1	8	8	2 to 3PCLK*5
0008 824Bh	SCI1	Transmit data register	TDR	8	8	2 to 3PCLK*5
0008 824Ch	SCI1	Serial status register	SSR*1	8	8	2 to 3PCLK*5
0008 824Dh	SCI1	Receive data register	RDR	8	8	2 to 3PCLK*5
0008 824Eh	SCI1	Smart card mode register	SCMR	8	8	2 to 3PCLK*5
0008 824Fh	SCI1	Serial extended mode register	SEMR	8	8	2 to 3PCLK*5
0008 8248h	SMCI1	Serial mode register	SMR	8	8	2 to 3PCLK*5
0008 8249h	SMCI1	Bit rate register	BRR	8	8	2 to 3PCLK*5
0008 824Ah	SMCI1	Serial control register	SCR	8	8	2 to 3PCLK*5
0008 824Bh	SMCI1	Transmit data register	TDR	8	8	2 to 3PCLK*5
0008 824Ch	SMCI1	Serial status register	SSR	8	8	2 to 3PCLK*5
0008 824Dh	SMCI1	Receive data register	RDR	8	8	2 to 3PCLK*5
0008 824Eh	SMCI1	Smart card mode register	SCMR	8	8	2 to 3PCLK*5

Table 5.1 List of I/O Registers (Address Order) (10 / 24)

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 8250h	SCI2	Serial mode register	SMR*1	8	8	2 to 3PCLK*5
0008 8251h	SCI2	Bit rate register	BRR	8	8	2 to 3PCLK*5
0008 8252h	SCI2	Serial control register	SCR*1	8	8	2 to 3PCLK*5
0008 8253h	SCI2	Transmit data register	TDR	8	8	2 to 3PCLK*5
0008 8254h	SCI2	Serial status register	SSR*1	8	8	2 to 3PCLK*5
0008 8255h	SCI2	Receive data register	RDR	8	8	2 to 3PCLK*5
0008 8256h	SCI2	Smart card mode register	SCMR	8	8	2 to 3PCLK*5
0008 8257h	SCI2	Serial extended mode register	SEMR	8	8	2 to 3PCLK*5
0008 8250h	SMCI2	Serial mode register	SMR*1	8	8	2 to 3PCLK*5
0008 8251h	SMCI2	Bit rate register	BRR	8	8	2 to 3PCLK*5
0008 8252h	SMCI2	Serial control register	SCR*1	8	8	2 to 3PCLK*5
0008 8253h	SMCI2	Transmit data register	TDR	8	8	2 to 3PCLK*5
0008 8254h	SMCI2	Serial status register	SSR*1	8	8	2 to 3PCLK*5
0008 8255h	SMCI2	Receive data register	RDR	8	8	2 to 3PCLK*5
0008 8256h	SMCI2	Smart card mode register	SCMR	8	8	2 to 3PCLK*5
0008 8280h	CRC	CRC control register	CRCCR	8	8	2 to 3PCLK*5
0008 8281h	CRC	CRC data input register	CRCDIR	8	8	2 to 3PCLK*5
0008 8282h	CRC	CRC data output register	CRCDOR	16	16	2 to 3PCLK*5
0008 8300h	RIIC	I^2C bus control register 1	ICCR1	8	8	2 to 3PCLK*5
0008 8301h	RIIC	I^2C bus control register 2	ICCR2	8	8	2 to 3PCLK*5
0008 8302h	RIIC	I^2C bus mode register 1	ICMR1	8	8	2 to 3PCLK*5
0008 8303h	RIIC	I^2C bus mode register 2	ICMR2	8	8	2 to 3PCLK*5
0008 8304h	RIIC	I^2C bus mode register 3	ICMR3	8	8	2 to 3PCLK*5
0008 8305h	RIIC	I^2C bus function enable register	ICFER	8	8	2 to 3PCLK*5
0008 8306h	RIIC	I^2C bus status enable register	ICSER	8	8	2 to 3PCLK*5
0008 8307h	RIIC	I^2C bus interrupt enable register	ICIER	8	8	2 to 3PCLK*5
0008 8308h	RIIC	I^2C bus status register 1	ICSR1	8	8	2 to 3PCLK*5
0008 8309h	RIIC	I^2C bus status register 2	ICSR2	8	8	2 to 3PCLK*5
0008 830Ah	RIIC	Slave address register L0	SARL0	8	8	2 to 3PCLK*5
0008 830Ah	RIIC	Timeout internal counter L	TMOCNTL	16	16	2 to 3PCLK*5
0008 830Bh	RIIC	Slave address register U0	SARU0	8	8	2 to 3PCLK*5
0008 830Bh	RIIC	Timeout internal counter U	TMOCNTU	16	16	2 to 3PCLK*5
0008 830Ch	RIIC	Slave address register L1	SARL1	8	8	2 to 3PCLK*5
0008 830Dh	RIIC	Slave address register U1	SARU1	8	8	2 to 3PCLK*5
0008 830Eh	RIIC	Slave address register L2	SARL2	8	8	2 to 3PCLK*5
0008 830Fh	RIIC	Slave address register U2	SARU2	8	8	2 to 3PCLK*5
0008 8310h	RIIC	I^2C bus bit rate low-level register	ICBRL	8	8	2 to 3PCLK*5
0008 8311h	RIIC	I^2C bus bit rate high-level register	ICBRH	8	8	2 to 3PCLK*5
0008 8312h	RIIC	I^2C bus transmit data register	ICDRT	8	8	2 to 3PCLK*5
0008 8313h	RIIC	I^2C bus receive data register	ICDRR	8	8	2 to 3PCLK*5
0008 8380h	RSPI	RSPI control register	SPCR	8	8	2 to 3PCLK*5
0008 8381h	RSPI	RSPI slave select polarity register	SSLP	8	8	2 to 3PCLK*5
0008 8382h	RSPI	RSPI pin control register	SPPCR	8	8	2 to 3PCLK*5
0008 8383h	RSPI	RSPI status register	SPSR	8	8	2 to 3PCLK*5

Table 5.1 List of I/O Registers (Address Order) (11 / 24)

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 8384h	RSPI	RSPI data register	SPDR	16, 32	16, 32	2 to 3PCLK*5
0008 8388h	RSPI	RSPI sequence control register	SPSCR	8	8	2 to 3PCLK*5
0008 8389h	RSPI	RSPI sequence status register	SPSSR	8	8	2 to 3PCLK*5
0008 838Ah	RSPI	RSPI bit rate register	SPBR	8	8	2 to 3PCLK*5
0008 838Bh	RSPI	RSPI data control register	SPDCR	8	8	2 to 3PCLK*5
0008 838Ch	RSPI	RSPI clock delay register	SPCKD	8	8	2 to 3PCLK*5
0008 838Dh	RSPI	RSPI slave select negation delay register	SSLND	8	8	2 to 3PCLK*5
0008 838Eh	RSPI	RSPI next-access delay register	SPND	8	8	2 to 3PCLK*5
0008 838Fh	RSPI	RSPI control register 2	SPCR2	8	8	2 to 3PCLK*5
0008 8390h	RSPI	RSPI command register 0	SPCMD0	16	16	2 to 3PCLK*5
0008 8392h	RSPI	RSPI command register 1	SPCMD1	16	16	2 to 3PCLK*5
0008 8394h	RSPI	RSPI command register 2	SPCMD2	16	16	2 to 3PCLK*5
0008 8396h	RSPI	RSPI command register 3	SPCMD3	16	16	2 to 3PCLK*5
0008 8398h	RSPI	RSPI command register 4	SPCMD4	16	16	2 to 3PCLK*5
0008 839Ah	RSPI	RSPI command register 5	SPCMD5	16	16	2 to 3PCLK*5
0008 839Ch	RSPI	RSPI command register 6	SPCMD6	16	16	2 to 3PCLK*5
0008 839Eh	RSPI	RSPI command register 7	SPCMD7	16	16	2 to 3PCLK*5
0008 9000h	S12AD0	A/D control register	ADCSR	8	8	2 to 3PCLK*5
0008 9004h	S12AD0	A/D channel select register	ADANS	16	16	2 to 3PCLK*5
0008 900Ah	S12AD0	A/D programmable gain amplifier register	ADPG	16	16	2 to 3PCLK*5
0008 900Eh	S12AD0	A/D control extended register	ADCER	16	16	2 to 3PCLK*5
0008 9010h	S12AD0	A/D start trigger select register	ADSTRGR	16	16	2 to 3PCLK*5
0008 9012h	S12AD	Comparator operating mode select register 0	ADCMPMD0	16	16	2 to 3PCLK*5
0008 9014h	S12AD	Comparator operating mode select register 1	ADCMPMD1	16	16	2 to 3PCLK*5
0008 9016h	S12AD	Comparator filter mode register 0	ADCMPNR0	16	16	2 to 3PCLK*5
0008 9018h	S12AD	Comparator filter mode register 1	ADCMPNR1	16	16	2 to 3PCLK*5
0008 901Ah	S12AD	Comparator detection flag register	ADCMPFR	8	8	2 to 3PCLK*5
0008 901Ch	S12AD	Comparator interrupt select register	ADCMPSEL	16	16	2 to 3PCLK*5
0008 901Eh	S12AD0	A/D data register Diag	ADRD	16	16	2 to 3PCLK*5
0008 9020h	S12AD0	A/D data register 0A	ADDR0A	16	16	2 to 3PCLK*5
0008 9022h	S12AD0	A/D data register 1	ADDR1	16	16	2 to 3PCLK*5
0008 9024h	S12AD0	A/D data register 2	ADDR2	16	16	2 to 3PCLK*5
0008 9026h	S12AD0	A/D data register 3	ADDR3	16	16	2 to 3PCLK*5
0008 9030h	S12AD0	A/D data register 0B	ADDR0B	16	16	2 to 3PCLK*5
0008 9060h	S12AD0	A/D sampling state register	ADSSTR	8	8	2 to 3PCLK*5
0008 9080h	S12AD1	A/D control register	ADCSR	8	8	2 to 3PCLK*5
0008 9084h	S12AD1	A/D channel select register	ADANS	16	16	2 to 3PCLK*5
0008 908Ah	S12AD1	A/D programmable gain amplifier register	ADPG	16	16	2 to 3PCLK*5
0008 908Eh	S12AD1	A/D control extended register	ADCER	16	16	2 to 3PCLK*5
0008 9090h	S12AD1	A/D start trigger select register	ADSTRGR	16	16	2 to 3PCLK*5
0008 909Eh	S12AD1	A/D data register Diag	ADRD	16	16	2 to 3PCLK*5
0008 90A0h	S12AD1	A/D data register 0A	ADDR0A	16	16	2 to 3PCLK*5
0008 90A2h	S12AD1	A/D data register 1	ADDR1	16	16	2 to 3PCLK*5
0008 90A4h	S12AD1	A/D data register 2	ADDR2	16	16	2 to 3PCLK*5

Table 5.1 List of I/O Registers (Address Order) (12 / 24)

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 90A6h	S12AD1	A/D data register 3	ADDR3	16	16	2 to 3PCLK*5
0008 90B0h	S12AD1	A/D data register 0B	ADDR0B	16	16	2 to 3PCLK*5
0008 90E0h	S12AD1	A/D sampling state register	ADSSTR	8	8	2 to 3PCLK*5
0008 C001h	PORT1	Data direction register	DDR	8	8	2 to 3PCLK*5
0008 C002h	PORT2	Data direction register	DDR	8	8	2 to 3PCLK*5
0008 C003h	PORT3	Data direction register	DDR	8	8	2 to 3PCLK*5
0008 C007h	PORT7	Data direction register	DDR	8	8	2 to 3PCLK*5
0008 C008h	PORT8	Data direction register	DDR*2*3	8	8	2 to 3PCLK*5
0008 C009h	PORT9	Data direction register	DDR	8	8	2 to 3PCLK*5
0008 C00Ah	PORTA	Data direction register	DDR	8	8	2 to 3PCLK*5
0008 C00Bh	PORTB	Data direction register	DDR	8	8	2 to 3PCLK*5
0008 C00Dh	PORTD	Data direction register	DDR	8	8	2 to 3PCLK*5
0008 C00Eh	PORTE	Data direction register	DDR	8	8	2 to 3PCLK*5
0008 C010h	PORTG	Data direction register	DDR*1*2*3	8	8	2 to 3PCLK*5
0008 C021h	PORT1	Data register	DR	8	8	2 to 3PCLK*5
0008 C022h	PORT2	Data register	DR	8	8	2 to 3PCLK*5
0008 C023h	PORT3	Data register	DR	8	8	2 to 3PCLK*5
0008 C027h	PORT7	Data register	DR	8	8	2 to 3PCLK*5
0008 C028h	PORT8	Data register	DR*2*3	8	8	2 to 3PCLK*5
0008 C029h	PORT9	Data register	DR	8	8	2 to 3PCLK*5
0008 C02Ah	PORTA	Data register	DR	8	8	2 to 3PCLK*5
0008 C02Bh	PORTB	Data register	DR	8	8	2 to 3PCLK*5
0008 C02Dh	PORTD	Data register	DR	8	8	2 to 3PCLK*5
0008 C02Eh	PORTE	Data register	DR	8	8	2 to 3PCLK*5
0008 C030h	PORTG	Data register	DR*1*2*3	8	8	2 to 3PCLK*5
0008 C041h	PORT1	Data register	PORT	8	8	2 to 3PCLK*5
0008 C042h	PORT2	Data register	PORT	8	8	2 to 3PCLK*5
0008 C043h	PORT3	Data register	PORT	8	8	2 to 3PCLK*5
0008 C044h	PORT4	Data register	PORT	8	8	2 to 3PCLK*5
0008 C045h	PORT5	Data register	PORT*2*3	8	8	2 to 3PCLK*5
0008 C046h	PORT6	Data register	PORT*3	8	8	2 to 3PCLK*5
0008 C047h	PORT7	Data register	PORT	8	8	2 to 3PCLK*5
0008 C048h	PORT8	Data register	PORT*2*3	8	8	2 to 3PCLK*5
0008 C049h	PORT9	Data register	PORT	8	8	2 to 3PCLK*5
0008 C04Ah	PORTA	Data register	PORT	8	8	2 to 3PCLK*5
0008 C04Bh	PORTB	Data register	PORT	8	8	2 to 3PCLK*5
0008 C04Dh	PORTD	Data register	PORT	8	8	2 to 3PCLK*5
0008 C04Eh	PORTE	Data register	PORT	8	8	2 to 3PCLK*5
0008 C050h	PORTG	Port register	PORT*1*2*3	8	8	2 to 3PCLK*5
0008 C061h	PORT1	Input buffer control register	ICR	8	8	2 to 3PCLK*5
0008 C062h	PORT2	Input buffer control register	ICR	8	8	2 to 3PCLK*5
0008 C063h	PORT3	Input buffer control register	ICR	8	8	2 to 3PCLK*5
0008 C064h	PORT4	Input buffer control register	ICR	8	8	2 to 3PCLK*5
0008 C065h	PORT5	Input buffer control register	ICR*2*3	8	8	2 to 3PCLK*5

Table 5.1 List of I/O Registers (Address Order) (13 / 24)

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 C066h	PORT6	Input buffer control register	ICR*3	8	8	2 to 3PCLK*5
0008 C067h	PORT7	Input buffer control register	ICR	8	8	2 to 3PCLK*5
0008 C068h	PORT8	Input buffer control register	ICR*2*3	8	8	2 to 3PCLK*5
0008 C069h	PORT9	Input buffer control register	ICR	8	8	2 to 3PCLK*5
0008 C06Ah	PORTA	Input buffer control register	ICR	8	8	2 to 3PCLK*5
0008 C06Bh	PORTB	Input buffer control register	ICR	8	8	2 to 3PCLK*5
0008 C06Dh	PORTD	Input buffer control register	ICR	8	8	2 to 3PCLK*5
0008 C06Eh	PORTE	Input buffer control register	ICR	8	8	2 to 3PCLK*5
0008 C070h	PORTG	Input buffer control register	ICR*1*2*3	8	8	2 to 3PCLK*5
0008 C108h	IOPORT	Port function register 8	PF8IRQ	8	8	2 to 3PCLK*5
0008 C109h	IOPORT	Port function register 9	PF9IRQ	8	8	2 to 3PCLK*5
0008 C10Ah	IOPORT	Port function register A	PFAADC	8	8	2 to 3PCLK*5
0008 C10Ch	IOPORT	Port function register C	PFCMTU	8	8	2 to 3PCLK*5
0008 C10Dh	IOPORT	Port function register D	PFDGPT	8	8	2 to 3PCLK*5
0008 C10Fh	IOPORT	Port function register F	PFFSCI	8	8	2 to 3PCLK*5
0008 C110h	IOPORT	Port function register G	PFGSPI	8	8	2 to 3PCLK*5
0008 C111h	IOPORT	Port function register H	PFHSPI	8	8	2 to 3PCLK*5
0008 C113h	IOPORT	Port function register J	PFJCAN	8	8	2 to 3PCLK*5
0008 C114h	IOPORT	Port function register K	PFKLIN	8	8	2 to 3PCLK*5
0008 C116h	IOPORT	Port function register M	PFMPOE	8	8	2 to 3PCLK*5
0008 C117h	IOPORT	Port function register N	PFNPOE	8	8	2 to 3PCLK*5
0008 C280h	SYSTEM	Deep standby control register	DPSBYCR	8	8	4 to 5PCLK*5
0008 C281h	SYSTEM	Deep standby wait control register	DPSWCR	8	8	4 to 5PCLK*5
0008 C282h	SYSTEM	Deep standby interrupt enable register	DPSIER	8	8	4 to 5PCLK*5
0008 C283h	SYSTEM	Deep standby interrupt flag register	DPSIFR	8	8	4 to 5PCLK*5
0008 C284h	SYSTEM	Deep standby interrupt edge register	DPSIEGR	8	8	4 to 5PCLK*5
0008 C285h	SYSTEM	Reset status register	RSTSR	8	8	4 to 5PCLK*5
0008 C289h	FLASH	Flash write erase protection register	FWEPROR	8	8	4 to 5PCLK*5
0008 C28Ch	SYSTEM	Key code register for low-voltage detection control register	LVDKEYR	8	8	4 to 5PCLK*5
0008 C28Dh	SYSTEM	Voltage detection control register	LVDCR	8	8	4 to 5PCLK*5
0008 C290h	SYSTEM	Deep standby backup register 0	DPSBKR0	8	8	4 to 5PCLK*5
0008 C291h	SYSTEM	Deep standby backup register 1	DPSBKR1	8	8	4 to 5PCLK*5
0008 C292h	SYSTEM	Deep standby backup register 2	DPSBKR2	8	8	4 to 5PCLK*5
0008 C293h	SYSTEM	Deep standby backup register 3	DPSBKR3	8	8	4 to 5PCLK*5
0008 C294h	SYSTEM	Deep standby backup register 4	DPSBKR4	8	8	4 to 5PCLK*5
0008 C295h	SYSTEM	Deep standby backup register 5	DPSBKR5	8	8	4 to 5PCLK*5
0008 C296h	SYSTEM	Deep standby backup register 6	DPSBKR6	8	8	4 to 5PCLK*5
0008 C297h	SYSTEM	Deep standby backup register 7	DPSBKR7	8	8	4 to 5PCLK*5
0008 C298h	SYSTEM	Deep standby backup register 8	DPSBKR8	8	8	4 to 5PCLK*5
0008 C299h	SYSTEM	Deep standby backup register 9	DPSBKR9	8	8	4 to 5PCLK*5
0008 C29Ah	SYSTEM	Deep standby backup register 10	DPSBKR10	8	8	4 to 5PCLK*5
0008 C29Bh	SYSTEM	Deep standby backup register 11	DPSBKR11	8	8	4 to 5PCLK*5
0008 C29Ch	SYSTEM	Deep standby backup register 12	DPSBKR12	8	8	4 to 5PCLK*5

Table 5.1 List of I/O Registers (Address Order) (14 / 24)

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 C29Dh	SYSTEM	Deep standby backup register 13	DPSBKR13	8	8	4 to 5PCLK*5
0008 C29Eh	SYSTEM	Deep standby backup register 14	DPSBKR14	8	8	4 to 5PCLK*5
0008 C29Fh	SYSTEM	Deep standby backup register 15	DPSBKR15	8	8	4 to 5PCLK*5
0008 C2A0h	SYSTEM	Deep standby backup register 16	DPSBKR16	8	8	4 to 5PCLK*5
0008 C2A1h	SYSTEM	Deep standby backup register 17	DPSBKR17	8	8	4 to 5PCLK*5
0008 C2A2h	SYSTEM	Deep standby backup register 18	DPSBKR18	8	8	4 to 5PCLK*5
0008 C2A3h	SYSTEM	Deep standby backup register 19	DPSBKR19	8	8	4 to 5PCLK*5
0008 C2A4h	SYSTEM	Deep standby backup register 20	DPSBKR20	8	8	4 to 5PCLK*5
0008 C2A5h	SYSTEM	Deep standby backup register 21	DPSBKR21	8	8	4 to 5PCLK*5
0008 C2A6h	SYSTEM	Deep standby backup register 22	DPSBKR22	8	8	4 to 5PCLK*5
0008 C2A7h	SYSTEM	Deep standby backup register 23	DPSBKR23	8	8	4 to 5PCLK*5
0008 C2A8h	SYSTEM	Deep standby backup register 24	DPSBKR24	8	8	4 to 5PCLK*5
0008 C2A9h	SYSTEM	Deep standby backup register 25	DPSBKR25	8	8	4 to 5PCLK*5
0008 C2AAh	SYSTEM	Deep standby backup register 26	DPSBKR26	8	8	4 to 5PCLK*5
0008 C2ABh	SYSTEM	Deep standby backup register 27	DPSBKR27	8	8	4 to 5PCLK*5
0008 C2ACh	SYSTEM	Deep standby backup register 28	DPSBKR28	8	8	4 to 5PCLK*5
0008 C2ADh	SYSTEM	Deep standby backup register 29	DPSBKR29	8	8	4 to 5PCLK*5
0008 C2AEh	SYSTEM	Deep standby backup register 30	DPSBKR30	8	8	4 to 5PCLK*5
0008 C2AFh	SYSTEM	Deep standby backup register 31	DPSBKR31	8	8	4 to 5PCLK*5
0008 C4C0h	POE	Input level control/status register 1	ICSR1	16	8, 16	2 to 3PCLK*5
0008 C4C2h	POE	Output level control/status register 1	OCSR1	16	8, 16	2 to 3PCLK*5
0008 C4C4h	POE	Input level control/status register 2	ICSR2	16	8, 16	2 to 3PCLK*5
0008 C4C6h	POE	Output level control/status register 2	OCSR2	16	8, 16	2 to 3PCLK*5
0008 C4C8h	POE	Input level control/status register 3	ICSR3	16	8, 16	2 to 3PCLK*5
0008 C4CAh	POE	Software port output enable register	SPOER	8	8	2 to 3PCLK*5
0008 C4CBh	POE	Port output enable control register 1	POECR1	8	8	2 to 3PCLK*5
0008 C4CCh	POE	Port output enable control register 2	POECR2	16	16	2 to 3PCLK*5
0008 C4CEh	POE	Port output enable control register 3	POECR3	16	16	2 to 3PCLK*5
0008 C4D0h	POE	Port output enable control register 4	POECR4	16	16	2 to 3PCLK*5
0008 C4D2h	POE	Port output enable control register 5	POECR5	16	16	2 to 3PCLK*5
0008 C4D4h	POE	Port output enable control register 6	POECR6	16	16	2 to 3PCLK*5
0008 C4D6h	POE	Input level control/status register 4	ICSR4	16	8, 16	2 to 3PCLK*5
0008 C4D8h	POE	Input level control/status register 5	ICSR5	16	8, 16	2 to 3PCLK*5
0008 C4DAh	POE	Active level setting register 1	ALR1	16	8, 16	2 to 3PCLK*5
0009 0200h to 0009 03FFh	CAN0*4	Mailbox registers 0 to 31	MB0 to MB 31	128	8, 16, 32	2 to 3PCLK*5
0009 0400h	CAN0*4	Mask register 0	MKR0	32	8, 16, 32	2 to 3PCLK*5
0009 0404h	CAN0*4	Mask register 1	MKR1	32	8, 16, 32	2 to 3PCLK*5
0009 0408h	CAN0*4	Mask register 2	MKR2	32	8, 16, 32	2 to 3PCLK*5
0009 040Ch	CAN0*4	Mask register 3	MKR3	32	8, 16, 32	2 to 3PCLK*5
0009 0410h	CAN0*4	Mask register 4	MKR4	32	8, 16, 32	2 to 3PCLK*5
0009 0414h	CAN0*4	Mask register 5	MKR5	32	8, 16, 32	2 to 3PCLK*5
0009 0418h	CAN0*4	Mask register 6	MKR6	32	8, 16, 32	2 to 3PCLK*5
0009 041Ch	CAN0*4	Mask register 7	MKR7	32	8, 16, 32	2 to 3PCLK*5

Table 5.1 List of I/O Registers (Address Order) (15 / 24)

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0009 0420h	CAN0*4	FIFO received ID compare register 0	FIDCR0	32	8, 16, 32	2 to 3PCLK*5
0009 0424h	CAN0*4	FIFO received ID compare register 1	FIDCR1	32	8, 16, 32	2 to 3PCLK*5
0009 0428h	CAN0*4	Mask invalid register	MKIVLR	32	8, 16, 32	2 to 3PCLK*5
0009 042Ch	CAN0*4	Mailbox interrupt enable register	MIER	32	8, 16, 32	2 to 3PCLK*5
0009 0820h to 0009 083Fh	CAN0*4	Message control registers 0 to 31	MCTL0 to MCTL31	8	8	2 to 3PCLK*5
0009 0840h	CAN0*4	Control register	CTLR	16	8, 16	2 to 3PCLK*5
0009 0842h	CAN0*4	Status register	STR	16	8, 16	2 to 3PCLK*5
0009 0844h	CAN0*4	Bit configuration register	BCR	32	8, 16, 32	2 to 3PCLK*5
0009 0848h	CAN0*4	Receive FIFO control register	RFCR	8	8	2 to 3PCLK*5
0009 0849h	CAN0*4	Receive FIFO pointer control register	RFPCR	8	8	2 to 3PCLK*5
0009 084Ah	CAN0*4	Transmit FIFO control register	TFCR	8	8	2 to 3PCLK*5
0009 084Bh	CAN0*4	Transmit FIFO pointer control register	TFPCR	8	8	2 to 3PCLK*5
0009 084Ch	CAN0*4	Error interrupt enable register	EIER	8	8	2 to 3PCLK*5
0009 084Dh	CAN0*4	Error interrupt factor judge register	EIFR	8	8	2 to 3PCLK*5
0009 084Eh	CAN0*4	Receive error count register	RECR	8	8	2 to 3PCLK*5
0009 084Fh	CAN0*4	Transmit error count register	TECR	8	8	2 to 3PCLK*5
0009 0850h	CAN0*4	Error code store register	ECSR	8	8	2 to 3PCLK*5
0009 0851h	CAN0*4	Channel search support register	CSSR	8	8	2 to 3PCLK*5
0009 0852h	CAN0*4	Mailbox search status register	MSSR	8	8	2 to 3PCLK*5
0009 0853h	CAN0*4	Mailbox search mode register	MSMR	8	8	2 to 3PCLK*5
0009 0854h	CAN0*4	Time stamp register	TSR	16	8, 16	2 to 3PCLK*5
0009 0856h	CAN0*4	Acceptance filter support register	AFSR	16	8, 16	2 to 3PCLK*5
0009 0858h	CAN0*4	Test control register	TCR	8	8	2 to 3PCLK*5
0009 4001h	LIN0	LIN wake-up baud rate select register	LWBR	8	8	2 to 3PCLK*5
0009 4002h	LIN0	LIN baud rate prescaler 0 register	LBRP0	8	8, 16	2 to 3PCLK*5
0009 4003h	LIN0	LIN baud rate prescaler 1 register	LBRP1	8	8, 16	2 to 3PCLK*5
0009 4004h	LIN0	LIN self-test control register	LSTC	8	8	2 to 3PCLK*5
0009 4008h	LIN0	Mode register	L0MD	8	8, 16, 32	2 to 3PCLK*5
0009 4009h	LIN0	Break field setting register	L0BRK	8	8, 16, 32	2 to 3PCLK*5
0009 400Ah	LIN0	Space setting register	L0SPC	8	8, 16, 32	2 to 3PCLK*5
0009 400Bh	LIN0	Wake-up setting register	L0WUP	8	8, 16, 32	2 to 3PCLK*5
0009 400Ch	LIN0	Interrupt enable register	L0IE	8	8, 16	2 to 3PCLK*5
0009 400Dh	LIN0	Error detection enable register	L0EDE	8	8, 16	2 to 3PCLK*5
0009 400Eh	LIN0	Control register	L0C	8	8	2 to 3PCLK*5
0009 4010h	LIN0	Transmission control register	L0TC	8	8, 16, 32	2 to 3PCLK*5
0009 4011h	LIN0	Mode status register	L0MST	8	8, 16, 32	2 to 3PCLK*5
0009 4012h	LIN0	Status register	L0ST	8	8, 16, 32	2 to 3PCLK*5
0009 4013h	LIN0	Error status register	L0EST	8	8, 16, 32	2 to 3PCLK*5
0009 4014h	LIN0	Response field set register	L0RFC	8	8, 16	2 to 3PCLK*5
0009 4015h	LIN0	Buffer register	L0IDB	8	8, 16	2 to 3PCLK*5
0009 4016h	LIN0	Check sum buffer register	L0CBR	8	8	2 to 3PCLK*5
0009 4018h	LIN0	Data 1 buffer register	L0DB1	8	8, 16, 32	2 to 3PCLK*5
0009 4019h	LIN0	Data 2 buffer register	L0DB2	8	8, 16, 32	2 to 3PCLK*5

Table 5.1 List of I/O Registers (Address Order) (16 / 24)

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0009 401Ah	LIN0	Data 3 buffer register	L0DB3	8	8, 16, 32	2 to 3PCLK*5
0009 401Bh	LIN0	Data 4 buffer register	L0DB4	8	8, 16, 32	2 to 3PCLK*5
0009 401Ch	LIN0	Data 5 buffer register	L0DB5	8	8, 16, 32	2 to 3PCLK*5
0009 401Dh	LIN0	Data 6 buffer register	L0DB6	8	8, 16, 32	2 to 3PCLK*5
0009 401Eh	LIN0	Data 7 buffer register	L0DB7	8	8, 16, 32	2 to 3PCLK*5
0009 401Fh	LIN0	Data 8 buffer register	L0DB8	8	8, 16, 32	2 to 3PCLK*5
000C 1200h	MTU3	Timer control register	TCR	8	8, 16, 32	5ICLK
000C 1201h	MTU4	Timer control register	TCR	8	8	5ICLK
000C 1202h	MTU3	Timer mode register 1	TMDR1	8	8, 16	5ICLK
000C 1203h	MTU4	Timer mode register 1	TMDR1	8	8	5ICLK
000C 1204h	MTU3	Timer I/O control register H	TIORH	8	8, 16, 32	5ICLK
000C 1205h	MTU3	Timer I/O control register L	TIORL	8	8	5ICLK
000C 1206h	MTU4	Timer I/O control register H	TIORH	8	8, 16	5ICLK
000C 1207h	MTU4	Timer I/O control register L	TIORL	8	8	5ICLK
000C 1208h	MTU3	Timer interrupt enable register	TIER	8	8, 16	5ICLK
000C 1209h	MTU4	Timer interrupt enable register	TIER	8	8	5ICLK
000C 120Ah	MTU	Timer output master enable register A	TOERA	8	8	5ICLK
000C 120Dh	MTU	Timer gate control register A	TGCRA	8	8	5ICLK
000C 120Eh	MTU	Timer output control register 1A	TOCR1A	8	8, 16	5ICLK
000C 120Fh	MTU	Timer output control register 2A	TOCR2A	8	8	5ICLK
000C 1210h	MTU3	Timer counter	TCNT	16	16, 32	5ICLK
000C 1212h	MTU4	Timer counter	TCNT	16	16	5ICLK
000C 1214h	MTU	Timer cycle data register A	TCDRA	16	16, 32	5ICLK
000C 1216h	MTU	Timer dead time data register A	TDDRA	16	16	5ICLK
000C 1218h	MTU3	Timer general register A	TGRA	16	16, 32	5ICLK
000C 121Ah	MTU3	Timer general register B	TGRB	16	16	5ICLK
000C 121Ch	MTU4	Timer general register A	TGRA	16	16, 32	5ICLK
000C 121Eh	MTU4	Timer general register B	TGRB	16	16	5ICLK
000C 1220h	MTU	Timer subcounter A	TCNTSA	16	16, 32	5ICLK
000C 1222h	MTU	Timer cycle buffer register A	TCBRA	16	16	5ICLK
000C 1224h	MTU3	Timer general register C	TGRC	16	16, 32	5ICLK
000C 1226h	MTU3	Timer general register D	TGRD	16	16	5ICLK
000C 1228h	MTU4	Timer general register C	TGRC	16	16, 32	5ICLK
000C 122Ah	MTU4	Timer general register D	TGRD	16	16	5ICLK
000C 122Ch	MTU3	Timer status register	TSR	8	8, 16	5ICLK
000C 122Dh	MTU4	Timer status register	TSR	8	8	5ICLK
000C 1230h	MTU	Timer interrupt skipping set register 1A	TITCR1A	8	8, 16	5ICLK
000C 1231h	MTU	Timer interrupt skipping counter 1A	TITCNT1A	8	8	5ICLK
000C 1232h	MTU	Timer buffer transfer set register A	TBTERA	8	8	5ICLK
000C 1234h	MTU	Timer dead time enable register A	TDERA	8	8	5ICLK
000C 1236h	MTU	Timer output level buffer register A	TOLBRA	8	8	5ICLK
000C 1238h	MTU3	Timer buffer operation transfer mode register	TBTM	8	8, 16	5ICLK
000C 1239h	MTU4	Timer buffer operation transfer mode register	TBTM	8	8	5ICLK
000C 123Ah	MTU	Timer interrupt skipping mode register A	TITMRA	8	8	5ICLK

Table 5.1 List of I/O Registers (Address Order) (17 / 24)

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
000C 123Bh	MTU	Timer interrupt skipping set register 2A	TITCR2A	8	8	5ICLK
000C 123Ch	MTU	Timer interrupt skipping counter 2A	TITCNT2A	8	8	5ICLK
000C 1240h	MTU4	Timer A/D converter start request control register	TADCR	16	16	5ICLK
000C 1244h	MTU4	Timer A/D converter start request cycle set register A	TADCORA	16	16, 32	5ICLK
000C 1246h	MTU4	Timer A/D converter start request cycle set register B	TADCORB	16	16	5ICLK
000C 1248h	MTU4	Timer A/D converter start request cycle set buffer register A	TADCOBRA	16	16, 32	5ICLK
000C 124Ah	MTU4	Timer A/D converter start request cycle set buffer register B	TADCOBRB	16	16	5ICLK
000C 1260h	MTU	Timer waveform control register A	TWCRA	8	8	5ICLK
000C 1270h	MTU3	Timer mode register 2A	TMDR2A	8	8	5ICLK
000C 1272h	MTU3	Timer general register E	TGRE	16	16	5ICLK
000C 1274h	MTU4	Timer general register E	TGRE	16	16	5ICLK
000C 1276h	MTU4	Timer general register F	TGRF	16	16	5ICLK
000C 1280h	MTU	Timer start register A	TSTRA	8	8, 16	5ICLK
000C 1281h	MTU	Timer synchronous register A	TSYRA	8	8	5ICLK
000C 1282h	MTU	Timer counter synchronous start register	TCSYSTR	8	8	5ICLK
000C 1284h	MTU	Timer read/write enable register A	TRWERA	8	8	5ICLK
000C 1300h	MTU0	Timer control register	TCR	8	8, 16, 32	5ICLK
000C 1301h	MTU0	Timer mode register 1	TMDR1	8	8	5ICLK
000C 1302h	MTU0	Timer I/O control register H	TIORH	8	8, 16	5ICLK
000C 1303h	MTU0	Timer I/O control register L	TIORL	8	8	5ICLK
000C 1304h	MTU0	Timer interrupt enable register	TIER	8	8, 16, 32	5ICLK
000C 1305h	MTU0	Timer status register	TSR	8	8	5ICLK
000C 1306h	MTU0	Timer counter	TCNT	16	16	5ICLK
000C 1308h	MTU0	Timer general register A	TGRA	16	16, 32	5ICLK
000C 130Ah	MTU0	Timer general register B	TGRB	16	16	5ICLK
000C 130Ch	MTU0	Timer general register C	TGRC	16	16, 32	5ICLK
000C 130Eh	MTU0	Timer general register D	TGRD	16	16	5ICLK
000C 1320h	MTU0	Timer general register E	TGRE	16	16, 32	5ICLK
000C 1322h	MTU0	Timer general register F	TGRF	16	16	5ICLK
000C 1324h	MTU0	Timer interrupt enable register 2	TIER2	8	8, 16	5ICLK
000C 1325h	MTU0	Timer status register 2	TSR2	8	8	5ICLK
000C 1326h	MTU0	Timer buffer operation transfer mode register	TBTM	8	8	5ICLK
000C 1380h	MTU1	Timer control register	TCR	8	8, 16	5ICLK
000C 1381h	MTU1	Timer mode register 1	TMDR1	8	8	5ICLK
000C 1382h	MTU1	Timer I/O control register	TIOR	8	8	5ICLK
000C 1384h	MTU1	Timer interrupt enable register	TIER	8	8, 16, 32	5ICLK
000C 1385h	MTU1	Timer status register	TSR	8	8	5ICLK
000C 1386h	MTU1	Timer counter	TCNT	16	16	5ICLK
000C 1388h	MTU1	Timer general register A	TGRA	16	16, 32	5ICLK
000C 138Ah	MTU1	Timer general register B	TGRB	16	16	5ICLK
000C 1390h	MTU1	Timer input capture control register	TICCR	8	8	5ICLK

Table 5.1 List of I/O Registers (Address Order) (18 / 24)

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
000C 1400h	MTU2	Timer control register	TCR	8	8, 16	5ICLK
000C 1401h	MTU2	Timer mode register 1	TMDR1	8	8	5ICLK
000C 1402h	MTU2	Timer I/O control register	TIOR	8	8	5ICLK
000C 1404h	MTU2	Timer interrupt enable register	TIER	8	8, 16, 32	5ICLK
000C 1405h	MTU2	Timer status register	TSR	8	8	5ICLK
000C 1406h	MTU2	Timer counter	TCNT	16	16	5ICLK
000C 1408h	MTU2	Timer general register A	TGRA	16	16, 32	5ICLK
000C 140Ah	MTU2	Timer general register B	TGRB	16	16	5ICLK
000C 1A00h	MTU6	Timer control register	TCR	8	8, 16, 32	5ICLK
000C 1A01h	MTU7	Timer control register	TCR	8	8	5ICLK
000C 1A02h	MTU6	Timer mode register 1	TMDR1	8	8, 16	5ICLK
000C 1A03h	MTU7	Timer mode register 1	TMDR1	8	8	5ICLK
000C 1A04h	MTU6	Timer I/O control register H	TIORH	8	8, 16, 32	5ICLK
000C 1A05h	MTU6	Timer I/O control register L	TIORL	8	8	5ICLK
000C 1A06h	MTU7	Timer I/O control register H	TIORH	8	8, 16	5ICLK
000C 1A07h	MTU7	Timer I/O control register L	TIORL	8	8	5ICLK
000C 1A08h	MTU6	Timer interrupt enable register	TIER	8	8, 16	5ICLK
000C 1A09h	MTU7	Timer interrupt enable register	TIER	8	8	5ICLK
000C 1A0Ah	MTU	Timer output master enable register B	TOERB	8	8	5ICLK
000C 1A0Eh	MTU	Timer output control register 1B	TOCR1B	8	8, 16	5ICLK
000C 1A0Fh	MTU	Timer output control register 2B	TOCR2B	8	8	5ICLK
000C 1A10h	MTU6	Timer counter	TCNT	16	16, 32	5ICLK
000C 1A12h	MTU7	Timer counter	TCNT	16	16	5ICLK
000C 1A14h	MTU	Timer cycle data register B	TCDRB	16	16, 32	5ICLK
000C 1A16h	MTU	Timer dead time data register B	TDDRB	16	16	5ICLK
000C 1A18h	MTU6	Timer general register A	TGRA	16	16, 32	5ICLK
000C 1A1Ah	MTU6	Timer general register B	TGRB	16	16	5ICLK
000C 1A1Ch	MTU7	Timer general register A	TGRA	16	16, 32	5ICLK
000C 1A1Eh	MTU7	Timer general register B	TGRB	16	16	5ICLK
000C 1A20h	MTU	Timer subcounter B	TCNTSB	16	16, 32	5ICLK
000C 1A22h	MTU	Timer cycle buffer register B	TCBRB	16	16	5ICLK
000C 1A24h	MTU6	Timer general register C	TGRC	16	16, 32	5ICLK
000C 1A26h	MTU6	Timer general register D	TGRD	16	16	5ICLK
000C 1A28h	MTU7	Timer general register C	TGRC	16	16, 32	5ICLK
000C 1A2Ah	MTU7	Timer general register D	TGRD	16	16	5ICLK
000C 1A2Ch	MTU6	Timer status register	TSR	8	8, 16	5ICLK
000C 1A2Dh	MTU7	Timer status register	TSR	8	8	5ICLK
000C 1A30h	MTU	Timer interrupt skipping set register 1B	TITCR1B	8	8, 16	5ICLK
000C 1A31h	MTU	Timer interrupt skipping counter 1B	TITCNT1B	8	8	5ICLK
000C 1A32h	MTU	Timer buffer transfer set register B	TBTERB	8	8	5ICLK
000C 1A34h	MTU	Timer dead time enable register B	TDERB	8	8	5ICLK
000C 1A36h	MTU	Timer output level buffer register B	TOLBRB	8	8	5ICLK
000C 1A38h	MTU6	Timer buffer operation transfer mode register	TBTM	8	8, 16	5ICLK
000C 1A39h	MTU7	Timer buffer operation transfer mode register	TBTM	8	8	5ICLK

Table 5.1 List of I/O Registers (Address Order) (19 / 24)

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
000C 1A3Ah	MTU	Timer interrupt skipping mode register B	TITMRB	8	8	5ICLK
000C 1A3Bh	MTU	Timer interrupt skipping set register 2B	TITCR2B	8	8	5ICLK
000C 1A3Ch	MTU	Timer interrupt skipping counter 2B	TITCNT2B	8	8	5ICLK
000C 1A40h	MTU7	Timer A/D converter start request control register	TADCR	16	16	5ICLK
000C 1A44h	MTU7	Timer A/D converter start request cycle set register A	TADCORA	16	16, 32	5ICLK
000C 1A46h	MTU7	Timer A/D converter start request cycle set register B	TADCORB	16	16	5ICLK
000C 1A48h	MTU7	Timer A/D converter start request cycle set buffer register A	TADCOBRA	16	16, 32	5ICLK
000C 1A4Ah	MTU7	Timer A/D converter start request cycle set buffer register B	TADCOBRB	16	16	5ICLK
000C 1A50h	MTU6	Timer synchronous clear register	TSYCR	8	8	5ICLK
000C 1A60h	MTU	Timer waveform control register B	TWCRB	8	8	5ICLK
000C 1A70h	MTU	Timer mode register 2B	TMDR2B	8	8	5ICLK
000C 1A72h	MTU6	Timer general register E	TGRE	16	16	5ICLK
000C 1A74h	MTU7	Timer general register E	TGRE	16	16	5ICLK
000C 1A76h	MTU7	Timer general register F	TGRF	16	16	5ICLK
000C 1A80h	MTU	Timer start register B	TSTRB	8	8, 16	5ICLK
000C 1A81h	MTU	Timer synchronous register B	TSYRB	8	8	5ICLK
000C 1A84h	MTU	Timer read/write enable register B	TRWERB	8	8	5ICLK
000C 1C80h	MTU5	Timer counter U	TCNTU	16	16, 32	5ICLK
000C 1C82h	MTU5	Timer general register U	TGRU	16	16	5ICLK
000C 1C84h	MTU5	Timer control register U	TCRU	8	8	5ICLK
000C 1C86h	MTU5	Timer I/O control register U	TIORU	8	8	5ICLK
000C 1C90h	MTU5	Timer counter V	TCNTV	16	16, 32	5ICLK
000C 1C92h	MTU5	Timer general register V	TGRV	16	16	5ICLK
000C 1C94h	MTU5	Timer control register V	TCRV	8	8	5ICLK
000C 1C96h	MTU5	Timer I/O control register V	TIORV	8	8	5ICLK
000C 1CA0h	MTU5	Timer counter W	TCNTW	16	16, 32	5ICLK
000C 1CA2h	MTU5	Timer general register W	TGRW	16	16	5ICLK
000C 1CA4h	MTU5	Timer control register W	TCRW	8	8	5ICLK
000C 1CA6h	MTU5	Timer I/O control register W	TIORW	8	8	5ICLK
000C 1CB0h	MTU5	Timer status register	TSR	8	8	5ICLK
000C 1CB2h	MTU5	Timer interrupt enable register	TIER	8	8	5ICLK
000C 1CB4h	MTU5	Timer start register	TSTR	8	8	5ICLK
000C 1CB6h	MTU5	Timer compare match clear register	TCNTCMPCLR	8	8	5ICLK
000C 2000h	GPT	General PWM timer software start register	GTSTR	16	8, 16, 32	3 to 5ICLK*6
000C 2004h	GPT	General PWM timer hardware source start control register	GTHSCR	16	8, 16, 32	3 to 5ICLK*6
000C 2006h	GPT	General PWM timer hardware source clear control register	GTHCCR	16	8, 16, 32	3 to 5ICLK*6
000C 2008h	GPT	General PWM timer hardware start source select register	GTHSSR	16	8, 16, 32	3 to 5ICLK*6

Table 5.1 List of I/O Registers (Address Order) (20 / 24)

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
000C 200Ah	GPT	General PWM timer hardware stop/clear source select register	GTHPSR	16	8, 16, 32	3 to 5ICLK*6
000C 200Ch	GPT	General PWM timer write-protection register	GTWP	16	8, 16, 32	3 to 5ICLK*6
000C 200Eh	GPT	General PWM timer sync register	GTSYNC	16	8, 16, 32	3 to 5ICLK*6
000C 2010h	GPT	General PWM timer external trigger input interrupt register	GTETINT	16	8, 16, 32	3 to 5ICLK*6
000C 2014h	GPT	General PWM timer buffer operation disable register	GTBDR	16	8, 16, 32	3 to 5ICLK*6
000C 2018h	GPT	General PWM timer start write protection register	GTSWP	16	16, 32	3 to 5ICLK*6
000C 2080h	GPT	LOCO count control register	LCCR	16	8, 16, 32	3 to 5ICLK*6
000C 2082h	GPT	LOCO count status register	LCST	16	8, 16, 32	3 to 5ICLK*6
000C 2084h	GPT	LOCO count value register	LCNT	16	8, 16, 32	3 to 5ICLK*6
000C 2086h	GPT	LOCO count result average register	LCNTA	16	8, 16, 32	3 to 5ICLK*6
000C 2088h	GPT	LOCO count result register 0	LCNT00	16	8, 16, 32	3 to 5ICLK*6
000C 208Ah	GPT	LOCO count result register 1	LCNT01	16	8, 16, 32	3 to 5ICLK*6
000C 208Ch	GPT	LOCO count result register 2	LCNT02	16	8, 16, 32	3 to 5ICLK*6
000C 208Eh	GPT	LOCO count result register 3	LCNT03	16	8, 16, 32	3 to 5ICLK*6
000C 2090h	GPT	LOCO count result register 4	LCNT04	16	8, 16, 32	3 to 5ICLK*6
000C 2092h	GPT	LOCO count result register 5	LCNT05	16	8, 16, 32	3 to 5ICLK*6
000C 2094h	GPT	LOCO count result register 6	LCNT06	16	8, 16, 32	3 to 5ICLK*6
000C 2096h	GPT	LOCO count result register 7	LCNT07	16	8, 16, 32	3 to 5ICLK*6
'000C 2098h	GPT	LOCO count result register 8	LCNT08	16	8, 16, 32	3 to 5ICLK*6
000C 209Ah	GPT	LOCO count result register 9	LCNT09	16	8, 16, 32	3 to 5ICLK*6
000C 209Ch	GPT	LOCO count result register 10	LCNT10	16	8, 16, 32	3 to 5ICLK*6
000C 209Eh	GPT	LOCO count result register 11	LCNT11	16	8, 16, 32	3 to 5ICLK*6
000C 20A0h	GPT	LOCO count result register 12	LCNT12	16	8, 16, 32	3 to 5ICLK*6
000C 20A2h	GPT	LOCO count result register 13	LCNT13	16	8, 16, 32	3 to 5ICLK*6
000C 20A4h	GPT	LOCO count result register 14	LCNT14	16	8, 16, 32	3 to 5ICLK*6
000C 20A6h	GPT	LOCO count result register 15	LCNT15	16	8, 16, 32	3 to 5ICLK*6
000C 20A8h	GPT	LOCO count upper permissible deviation register	LCNTDU	16	8, 16, 32	3 to 5ICLK*6
000C 20AAh	GPT	LOCO count lower permissible deviation register	LCNTDL	16	8, 16, 32	3 to 5ICLK*6
000C 2100h	GPT0	General PWM timer I/O control register	GTIOR	16	8, 16, 32	3 to 5ICLK*6
000C 2102h	GPT0	General PWM timer interrupt output setting register	GTINTAD	16	8, 16, 32	3 to 5ICLK*6
000C 2104h	GPT0	General PWM timer control register	GTCR	16	8, 16, 32	3 to 5ICLK*6
000C 2106h	GPT0	General PWM timer buffer enable register	GTBER	16	8, 16, 32	3 to 5ICLK*6
000C 2108h	GPT0	General PWM timer count direction register	GTUDC	16	8, 16, 32	3 to 5ICLK*6
000C 210Ah	GPT0	General PWM timer interrupt and A/D converter start request skipping setting register	GTITC	16	8, 16, 32	3 to 5ICLK*6
000C 210Ch	GPT0	General PWM timer status register	GTST	16	8, 16, 32	3 to 5ICLK*6
000C 210Eh	GPT0	General PWM timer counter	GTCNT	16	16	3 to 5ICLK*6
000C 2110h	GPT0	General PWM timer compare capture register A	GTCCRA	16	16, 32	3 to 5ICLK*6
000C 2112h	GPT0	General PWM timer compare capture register B	GTCCRB	16	16, 32	3 to 5ICLK*6
000C 2114h	GPT0	General PWM timer compare capture register C	GTCCRC	16	16, 32	3 to 5ICLK*6

Table 5.1 List of I/O Registers (Address Order) (21 / 24)

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
000C 2116h	GPT0	General PWM timer compare capture register D	GTCCRD	16	16, 32	3 to 5ICLK*6
000C 2118h	GPT0	General PWM timer compare capture register E	GTCCRE	16	16, 32	3 to 5ICLK*6
000C 211Ah	GPT0	General PWM timer compare capture register F	GTCCRF	16	16, 32	3 to 5ICLK*6
000C 211Ch	GPT0	General PWM timer cycle setting register	GTPR	16	16, 32	3 to 5ICLK*6
000C 211Eh	GPT0	General PWM timer cycle setting buffer register	GTPBR	16	16, 32	3 to 5ICLK*6
000C 2120h	GPT0	General PWM timer cycle setting double-buffer register	GTPDBR	16	16, 32	3 to 5ICLK*6
000C 2124h	GPT0	A/D converter start request timing register A	GTADTRA	16	16, 32	3 to 5ICLK*6
000C 2126h	GPT0	A/D converter start request timing buffer register A	GTADTBRA	16	16, 32	3 to 5ICLK*6
000C 2128h	GPT0	A/D converter start request timing double-buffer register A	GTADTDBRA	16	16, 32	3 to 5ICLK*6
000C 212Ch	GPT0	A/D converter start request timing register B	GTADTRB	16	16, 32	3 to 5ICLK*6
000C 212Eh	GPT0	A/D converter start request timing buffer register B	GTADTBRB	16	16, 32	3 to 5ICLK*6
000C 2130h	GPT0	A/D converter start request timing double-buffer register B	GTADTDBRB	16	16, 32	3 to 5ICLK*6
000C 2134h	GPT0	General PWM timer output negate control register	GTONCR	16	16, 32	3 to 5ICLK*6
000C 2136h	GPT0	General PWM timer dead time control register	GTDTCR	16	16, 32	3 to 5ICLK*6
000C 2138h	GPT0	General PWM timer dead time value register	GTDVU	16	16, 32	3 to 5ICLK*6
000C 213Ah	GPT0	General PWM timer dead time value register	GTDVD	16	16, 32	3 to 5ICLK*6
000C 213Ch	GPT0	General PWM timer dead time buffer register	GTDBU	16	16, 32	3 to 5ICLK*6
000C 213Eh	GPT0	General PWM timer dead time buffer register	GTDBD	16	16, 32	3 to 5ICLK*6
000C 2140h	GPT0	General PWM timer output protection function status register	GTSOS	16	16, 32	3 to 5ICLK*6
000C 2142h	GPT0	General PWM timer output protection function temporary release register	GTSOTR	16	16, 32	3 to 5ICLK*6
000C 2180h	GPT1	General PWM timer I/O control register	GTIOR	16	8, 16, 32	3 to 5ICLK*6
000C 2182h	GPT1	General PWM timer interrupt output setting register	GTINTAD	16	8, 16, 32	3 to 5ICLK*6
000C 2184h	GPT1	General PWM timer control register	GTCR	16	8, 16, 32	3 to 5ICLK*6
000C 2186h	GPT1	General PWM timer buffer enable register	GTBER	16	8, 16, 32	3 to 5ICLK*6
000C 2188h	GPT1	General PWM timer count direction register	GTUDC	16	8, 16, 32	3 to 5ICLK*6
000C 218Ah	GPT1	General PWM timer interrupt and A/D converter start request skipping setting register	GTITC	16	8, 16, 32	3 to 5ICLK*6
000C 218Ch	GPT1	General PWM timer status register	GTST	16	8, 16, 32	3 to 5ICLK*6
000C 218Eh	GPT1	General PWM timer counter	GTCNT	16	16	3 to 5ICLK*6
000C 2190h	GPT1	General PWM timer compare capture register A	GTCCRA	16	16, 32	3 to 5ICLK*6
000C 2192h	GPT1	General PWM timer compare capture register B	GTCCRB	16	16, 32	3 to 5ICLK*6
000C 2194h	GPT1	General PWM timer compare capture register C	GTCCRC	16	16, 32	3 to 5ICLK*6
000C 2196h	GPT1	General PWM timer compare capture register D	GTCCRD	16	16, 32	3 to 5ICLK*6
000C 2198h	GPT1	General PWM timer compare capture register E	GTCCRE	16	16, 32	3 to 5ICLK*6
000C 219Ah	GPT1	General PWM timer compare capture register F	GTCCRF	16	16, 32	3 to 5ICLK*6
000C 219Ch	GPT1	General PWM timer cycle setting register	GTPR	16	16, 32	3 to 5ICLK*6
000C 219Eh	GPT1	General PWM timer cycle setting buffer register	GTPBR	16	16, 32	3 to 5ICLK*6

Table 5.1 List of I/O Registers (Address Order) (22 / 24)

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
000C 21A0h	GPT1	General PWM timer cycle setting double-buffer register	GTPDBR	16	16, 32	3 to 5ICLK*6
000C 21A4h	GPT1	A/D converter start request timing register A	GTADTRA	16	16, 32	3 to 5ICLK*6
000C 21A6h	GPT1	A/D converter start request timing buffer register A	GTADTBRA	16	16, 32	3 to 5ICLK*6
000C 21A8h	GPT1	A/D converter start request timing double-buffer register A	GTADTDBRA	16	16, 32	3 to 5ICLK*6
000C 21ACh	GPT1	A/D converter start request timing register B	GTADTRB	16	16, 32	3 to 5ICLK*6
000C 21AEh	GPT1	A/D converter start request timing buffer register B	GTADTBRB	16	16, 32	3 to 5ICLK*6
000C 21B0h	GPT1	A/D converter start request timing double-buffer register B	GTADTDBRB	16	16, 32	3 to 5ICLK*6
000C 21B4h	GPT1	General PWM timer output negate control register	GTONCR	16	16, 32	3 to 5ICLK*6
000C 21B6h	GPT1	General PWM timer dead time control register	GTDTCR	16	16, 32	3 to 5ICLK*6
000C 21B8h	GPT1	General PWM timer dead time value register	GTDVU	16	16, 32	3 to 5ICLK*6
000C 21BAh	GPT1	General PWM timer dead time value register	GTDVD	16	16, 32	3 to 5ICLK*6
000C 21BCh	GPT1	General PWM timer dead time buffer register	GTDBU	16	16, 32	3 to 5ICLK*6
000C 21BEh	GPT1	General PWM timer dead time buffer register	GTDBD	16	16, 32	3 to 5ICLK*6
000C 21C0h	GPT1	General PWM timer output protection function status register	GTSOS	16	16, 32	3 to 5ICLK*6
000C 21C2h	GPT1	General PWM timer output protection temporary release register	GTSOTR	16	16, 32	3 to 5ICLK*6
000C 2200h	GPT2	General PWM timer I/O control register	GTIOR	16	8, 16, 32	3 to 5ICLK*6
000C 2202h	GPT2	General PWM timer interrupt output setting register	GTINTAD	16	8, 16, 32	3 to 5ICLK*6
000C 2204h	GPT2	General PWM timer control register	GTCR	16	8, 16, 32	3 to 5ICLK*6
000C 2206h	GPT2	General PWM timer buffer enable register	GTBER	16	8, 16, 32	3 to 5ICLK*6
000C 2208h	GPT2	General PWM timer count direction register	GTUDC	16	8, 16, 32	3 to 5ICLK*6
000C 220Ah	GPT2	General PWM timer interrupt and A/D converter start request skipping setting register	GTITC	16	8, 16, 32	3 to 5ICLK*6
000C 220Ch	GPT2	General PWM timer status register	GTST	16	8, 16, 32	3 to 5ICLK*6
000C 220Eh	GPT2	General PWM timer counter	GTCNT	16	16	3 to 5ICLK*6
000C 2210h	GPT2	General PWM timer compare capture register A	GTCCRA	16	16, 32	3 to 5ICLK*6
000C 2212h	GPT2	General PWM timer compare capture register B	GTCCRB	16	16, 32	3 to 5ICLK*6
000C 2214h	GPT2	General PWM timer compare capture register C	GTCCRC	16	16, 32	3 to 5ICLK*6
000C 2216h	GPT2	General PWM timer compare capture register D	GTCCRD	16	16, 32	3 to 5ICLK*6
000C 2218h	GPT2	General PWM timer compare capture register E	GTCCRE	16	16, 32	3 to 5ICLK*6
000C 221Ah	GPT2	General PWM timer compare capture register F	GTCCRF	16	16, 32	3 to 5ICLK*6
000C 221Ch	GPT2	General PWM timer cycle setting register	GTPR	16	16, 32	3 to 5ICLK*6
000C 221Eh	GPT2	General PWM timer cycle setting buffer register	GTPBR	16	16, 32	3 to 5ICLK*6
000C 2220h	GPT2	General PWM timer cycle setting double-buffer register	GTPDBR	16	16, 32	3 to 5ICLK*6
000C 2224h	GPT2	A/D converter start request timing register A	GTADTRA	16	16, 32	3 to 5ICLK*6
000C 2226h	GPT2	A/D converter start request timing buffer register A	GTADTBRA	16	16, 32	3 to 5ICLK*6
000C 2228h	GPT2	A/D converter start request timing double-buffer register A	GTADTDBRA	16	16, 32	3 to 5ICLK*6

Table 5.1 List of I/O Registers (Address Order) (23 / 24)

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
000C 222Ch	GPT2	A/D converter start request timing register B	GTADTRB	16	16, 32	3 to 5ICLK*6
000C 222Eh	GPT2	A/D converter start request timing buffer register B	GTADTBRB	16	16, 32	3 to 5ICLK*6
000C 2230h	GPT2	A/D converter start request timing double-buffer register B	GTADTDBRB	16	16, 32	3 to 5ICLK*6
000C 2234h	GPT2	General PWM timer output negate control register	GTONCR	16	16, 32	3 to 5ICLK*6
000C 2236h	GPT2	General PWM timer dead time control register	GTDTCR	16	16, 32	3 to 5ICLK*6
000C 2238h	GPT2	General PWM timer dead time value register	GTDVU	16	16, 32	3 to 5ICLK*6
000C 223Ah	GPT2	General PWM timer dead time value register	GTDVD	16	16, 32	3 to 5ICLK*6
000C 223Ch	GPT2	General PWM timer dead time buffer register	GTDBU	16	16, 32	3 to 5ICLK*6
000C 223Eh	GPT2	General PWM timer dead time buffer register	GTDBD	16	16, 32	3 to 5ICLK*6
000C 2240h	GPT2	General PWM timer output protection function status register	GTSOS	16	16, 32	3 to 5ICLK*6
000C 2242h	GPT2	General PWM timer output protection temporary release register	GTSOTR	16	16, 32	3 to 5ICLK*6
000C 2280h	GPT3	General PWM timer I/O control register	GTIOR	16	8, 16, 32	3 to 5ICLK*6
000C 2282h	GPT3	General PWM timer interrupt output setting register	GTINTAD	16	8, 16, 32	3 to 5ICLK*6
000C 2284h	GPT3	General PWM timer control register	GTCR	16	8, 16, 32	3 to 5ICLK*6
000C 2286h	GPT3	General PWM timer buffer enable register	GTBER	16	8, 16, 32	3 to 5ICLK*6
000C 2288h	GPT3	General PWM timer count direction register	GTUDC	16	8, 16, 32	3 to 5ICLK*6
000C 228Ah	GPT3	General PWM timer interrupt and A/D converter start request skipping setting register	GTITC	16	8, 16, 32	3 to 5ICLK*6
000C 228Ch	GPT3	General PWM timer status register	GTST	16	8, 16, 32	3 to 5ICLK*6
000C 228Eh	GPT3	General PWM timer counter	GTCNT	16	16	3 to 5ICLK*6
000C 2290h	GPT3	General PWM timer compare capture register A	GTCCRA	16	16, 32	3 to 5ICLK*6
000C 2292h	GPT3	General PWM timer compare capture register B	GTCCRB	16	16, 32	3 to 5ICLK*6
000C 2294h	GPT3	General PWM timer compare capture register C	GTCCRC	16	16, 32	3 to 5ICLK*6
000C 2296h	GPT3	General PWM timer compare capture register D	GTCCRD	16	16, 32	3 to 5ICLK*6
000C 2298h	GPT3	General PWM timer compare capture register E	GTCCRE	16	16, 32	3 to 5ICLK*6
000C 229Ah	GPT3	General PWM timer compare capture register F	GTCCRF	16	16, 32	3 to 5ICLK*6
000C 229Ch	GPT3	General PWM timer cycle setting register	GTPR	16	16, 32	3 to 5ICLK*6
000C 229Eh	GPT3	General PWM timer cycle setting buffer register	GTPBR	16	16, 32	3 to 5ICLK*6
000C 22A0h	GPT3	General PWM timer cycle setting double-buffer register	GTPDBR	16	16, 32	3 to 5ICLK*6
000C 22A4h	GPT3	A/D converter start request timing register A	GTADTRA	16	16, 32	3 to 5ICLK*6
000C 22A6h	GPT3	A/D converter start request timing buffer register A	GTADTBRA	16	16, 32	3 to 5ICLK*6
000C 22A8h	GPT3	A/D converter start request timing double-buffer register A	GTADTDBRA	16	16, 32	3 to 5ICLK*6
000C 22ACh	GPT3	A/D converter start request timing register B	GTADTRB	16	16, 32	3 to 5ICLK*6
000C 22AEh	GPT3	A/D converter start request timing buffer register B	GTADTBRB	16	16, 32	3 to 5ICLK*6
000C 22B0h	GPT3	A/D converter start request timing double-buffer register B	GTADTDBRB	16	16, 32	3 to 5ICLK*6
000C 22B4h	GPT3	General PWM timer output negate control register	GTONCR	16	16, 32	3 to 5ICLK*6

Table 5.1 List of I/O Registers (Address Order) (24 / 24)

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
000C 22B6h	GPT3	General PWM timer dead time control register	GTDTCR	16	16, 32	3 to 5ICLK*6
000C 22B8h	GPT3	General PWM timer dead time value register	GTDVU	16	16, 32	3 to 5ICLK*6
000C 22BAh	GPT3	General PWM timer dead time value register	GTDVD	16	16, 32	3 to 5ICLK*6
000C 22BCh	GPT3	General PWM timer dead time buffer register	GTDBU	16	16, 32	3 to 5ICLK*6
000C 22BEh	GPT3	General PWM timer dead time buffer register	GTDBD	16	16, 32	3 to 5ICLK*6
000C 22C0h	GPT3	General PWM timer output protection function status register	GTSOS	16	16, 32	3 to 5ICLK*6
000C 22C2h	GPT3	General PWM timer output protection temporary release register	GTSOTR	16	16, 32	3 to 5ICLK*6
007F C402h	FLASH	Flash mode register	FMODR	8	8	2 to 3PCLK*5
007F C410h	FLASH	Flash access status register	FASTAT	8	8	2 to 3PCLK*5
007F C411h	FLASH	Flash access error interrupt enable register	FAEINT	8	8	2 to 3PCLK*5
007F C412h	FLASH	Flash ready interrupt enable register	FRDYIE	8	8	2 to 3PCLK*5
007F C440h	FLASH	Data flash read enable register 0	DFLRE0	16	16	2 to 3PCLK*5
007F C442h	FLASH	Data flash read enable register 1	DFLRE1	16	16	2 to 3PCLK*5
007F C450h	FLASH	Data flash programming/erasure enable register 0	DFLWE0	16	16	2 to 3PCLK*5
007F C452h	FLASH	Data flash programming/erasure enable register 1	DFLWE1	16	16	2 to 3PCLK*5
007F C454h	FLASH	FCU RAM enable register	FCURAME	16	16	2 to 3PCLK*5
007F FFB0h	FLASH	Flash status register 0	FSTATR0	8	8	2 to 3PCLK*5
007F FFB1h	FLASH	Flash status register 1	FSTATR1	8	8	2 to 3PCLK*5
007F FFB2h	FLASH	Flash P/E mode entry register	FENTRYR	16	16	2 to 3PCLK*5
007F FFB4h	FLASH	Flash protect register	FPROTR	16	16	2 to 3PCLK*5
007F FFB6h	FLASH	Flash reset register	FRESETR	16	16	2 to 3PCLK*5
007F FFBAh	FLASH	FCU command register	FCMDR	16	16	2 to 3PCLK*5
007F FFC8h	FLASH	FCU processing switching register	FCPSR	16	16	2 to 3PCLK*5
007F FFCAh	FLASH	Data flash blank check control register	DFLBCCNT	16	16	2 to 3PCLK*5
007F FFCCh	FLASH	Flash P/E status register	FPESTAT	16	16	2 to 3PCLK*5
007F FFCEh	FLASH	Data flash blank check status register	DFLBCSTAT	16	16	2 to 3PCLK*5
007F FFE8h	FLASH	Peripheral clock notification register	PCKAR	16	16	2 to 3PCLK*5

Note 1. This register is not supported by the 100-pin LQFP version.
Note 2. This register is not supported by the 80-pin LQFP version.
Note 3. This register is not supported by the 64-pin LQFP version.
Note 4. This register is not supported by the product without the CAN function.
Note 5. The number of access states depends on the number of divided cycles for clock synchronization (0 to 1 PCLK).
Note 6. Reading the registers takes 3 cycles of ICLK and writing to the registers takes 5 cycles of ICLK.

5.2 I/O Register Bits

Register addresses and bit names of the peripheral modules are described below.
Each line cover eight bits, and 16-bit and 32-bit registers are shown as 2 or 4 lines, respectively.

Table 5.2 List of I/O Registers (Bit Order) (1 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
SYSTEM	MDMONR	—	—	—	—	—	—	—	—
		MDE	—	—	—	—	—	MD1	MD0
SYSTEM	MDSR	—	—	—	—	—	—	—	—
		—	—	—	BOTS	—	—	—	IROM
SYSTEM	SYSCR0	KEY[7:0]							
		—	—	—	—	—	—	—	ROME
SYSTEM	SYSCR1	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	RAME
SYSTEM	SBYCR	SSBY	—	—	STS[4:0]				
		—	—	—	—	—	—	—	—
SYSTEM	MSTPCRA	ACSE	—	—	MSTPA28	—	—	—	MSTPA24
		MSTPA23	—	—	—	—	—	MSTPA17	MSTPA16
		MSTPA15	MSTPA14	—	—	—	—	MSTPA9	—
		MSTPA7	—	—	—	—	—	—	—
SYSTEM	MSTPCRB	MSTPB31	MSTPB30	MSTPB29	—	—	—	—	—
		MSTPB23	—	MSTPB21	—	—	—	MSTPB17	—
		—	—	—	—	—	—	—	—
		MSTPB7	—	—	—	—	—	—	MSTPB0
SYSTEM	MSTPCRC	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	MSTPC0
SYSTEM	SCKCR	—	—	—	—	ICK[3:0]			
		—	—	—	—	—	—	—	—
		—	—	—	—	PCK[3:0]			
		—	—	—	—	—	—	—	—
SYSTEM	OSTDCR	KEY[7:0]							
		OSTDE	OSTDF	—	—	—	—	—	—
BSC	BERCLR	—	—	—	—	—	—	—	STSCLR
BSC	BEREN	—	—	—	—	—	—	—	IGAEN
BSC	BERSR1	—	MST[2:0]			—	—	—	IA
BSC	BERSR2	ADDR[12:0]							
		ADDR[12:0]					—	—	—
DTC	DTCCR	—	—	—	RRS	—	—	—	—
DTC	DTCVBR								
DTC	DTCADMOD	—	—	—	—	—	—	—	SHORT
DTC	DTCST	—	—	—	—	—	—	—	DTCST

Table 5.2 List of I/O Registers (Bit Order) (2 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
DTC	DTCSTS	ACT	—	—	—	—	—	—	—
		VECN[7:0]							
MPU	RSPAGE0	RSPN[27:0]							
		RSPN[27:0]							
		RSPN[27:0]							
		RSPN[27:0]				—	—	—	—
MPU	REPAGE0	REPN[27:0]							
		REPN[27:0]							
		REPN[27:0]							
		REPN[27:0]				UAC[2:0]			V
MPU	RSPAGE1	RSPN[27:0]							
		RSPN[27:0]							
		RSPN[27:0]							
		RSPN[27:0]				—	—	—	—
MPU	REPAGE1	REPN[27:0]							
		REPN[27:0]							
		REPN[27:0]							
		REPN[27:0]				UAC[2:0]			V
MPU	RSPAGE2	RSPN[27:0]							
		RSPN[27:0]							
		RSPN[27:0]							
		RSPN[27:0]				—	—	—	—
MPU	REPAGE2	REPN[27:0]							
		REPN[27:0]							
		REPN[27:0]							
		REPN[27:0]				UAC[2:0]			V
MPU	RSPAGE3	RSPN[27:0]							
		RSPN[27:0]							
		RSPN[27:0]							
		RSPN[27:0]				—	—	—	—
MPU	REPAGE3	REPN[27:0]							
		REPN[27:0]							
		REPN[27:0]							
		REPN[27:0]				UAC[2:0]			V
MPU	RSPAGE4	RSPN[27:0]							
		RSPN[27:0]							
		RSPN[27:0]							
		RSPN[27:0]				—	—	—	—
MPU	REPAGE4	REPN[27:0]							
		REPN[27:0]							
		REPN[27:0]							
		REPN[27:0]				UAC[2:0]			V

Table 5.2 List of I/O Registers (Bit Order) (3 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
MPU	RSPAGE5	RSPN[27:0]							
		RSPN[27:0]							
		RSPN[27:0]							
		RSPN[27:0]				—	—	—	—
MPU	REPAGE5	REPN[27:0]							
		REPN[27:0]							
		REPN[27:0]							
		REPN[27:0]				UAC[2:0]			V
MPU	RSPAGE6	RSPN[27:0]							
		RSPN[27:0]							
		RSPN[27:0]							
		RSPN[27:0]				—	—	—	—
MPU	REPAGE6	REPN[27:0]							
		REPN[27:0]							
		REPN[27:0]							
		REPN[27:0]				UAC[2:0]			V
MPU	RSPAGE7	RSPN[27:0]							
		RSPN[27:0]							
		RSPN[27:0]							
		RSPN[27:0]				—	—	—	—
MPU	REPAGE7	REPN[27:0]							
		REPN[27:0]							
		REPN[27:0]							
		REPN[27:0]				UAC[2:0]			V
MPU	MPEN	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	MPEN
MPU	MPBAC	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	—
		—	—	—	—	UBAC[2:0]			—
MPU	MPECLR	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	CLR
MPU	MPESTS	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	—
		—	—	—	—	—	DRW	DA	IA
MPU	MPDEA	DEA[31:0]							
		DEA[31:0]							
		DEA[31:0]							
		DEA[31:0]							

Table 5.2 List of I/O Registers (Bit Order) (4 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
MPU	MPSA	SA[31:0]							
		SA[31:0]							
		SA[31:0]							
		SA[31:0]							
MPU	MPOPS	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	S
MPU	MPOPI	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	INV
MPU	MHITI	—	—	—	—	—	—	—	—
		HITI[7:0]							
		—	—	—	—	—	—	—	—
		—	—	—	—	UHACI[2:0]			—
MPU	MHITD	—	—	—	—	—	—	—	—
		HITD[7:0]							
		—	—	—	—	—	—	—	—
		—	—	—	—	UHACD[2:0]			—
ICU	IR016	—	—	—	—	—	—	—	IR
ICU	IR021	—	—	—	—	—	—	—	IR
ICU	IR023	—	—	—	—	—	—	—	IR
ICU	IR027	—	—	—	—	—	—	—	IR
ICU	IR028	—	—	—	—	—	—	—	IR
ICU	IR029	—	—	—	—	—	—	—	IR
ICU	IR030	—	—	—	—	—	—	—	IR
ICU	IR031	—	—	—	—	—	—	—	IR
ICU	IR044	—	—	—	—	—	—	—	IR
ICU	IR045	—	—	—	—	—	—	—	IR
ICU	IR046	—	—	—	—	—	—	—	IR
ICU	IR047	—	—	—	—	—	—	—	IR
ICU	IR056	—	—	—	—	—	—	—	IR
ICU	IR057	—	—	—	—	—	—	—	IR
ICU	IR058	—	—	—	—	—	—	—	IR
ICU	IR059	—	—	—	—	—	—	—	IR
ICU	IR060	—	—	—	—	—	—	—	IR
ICU	IR064	—	—	—	—	—	—	—	IR
ICU	IR065	—	—	—	—	—	—	—	IR
ICU	IR066	—	—	—	—	—	—	—	IR
ICU	IR067	—	—	—	—	—	—	—	IR
ICU	IR068	—	—	—	—	—	—	—	IR
ICU	IR069	—	—	—	—	—	—	—	IR
ICU	IR070	—	—	—	—	—	—	—	IR
ICU	IR071	—	—	—	—	—	—	—	IR
ICU	IR096	—	—	—	—	—	—	—	IR
ICU	IR098	—	—	—	—	—	—	—	IR
ICU	IR102	—	—	—	—	—	—	—	IR
ICU	IR103	—	—	—	—	—	—	—	IR

Table 5.2 List of I/O Registers (Bit Order) (5 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
ICU	IR106	—	—	—	—	—	—	—	IR
ICU	IR114	—	—	—	—	—	—	—	IR
ICU	IR115	—	—	—	—	—	—	—	IR
ICU	IR116	—	—	—	—	—	—	—	IR
ICU	IR117	—	—	—	—	—	—	—	IR
ICU	IR118	—	—	—	—	—	—	—	IR
ICU	IR119	—	—	—	—	—	—	—	IR
ICU	IR120	—	—	—	—	—	—	—	IR
ICU	IR121	—	—	—	—	—	—	—	IR
ICU	IR122	—	—	—	—	—	—	—	IR
ICU	IR123	—	—	—	—	—	—	—	IR
ICU	IR124	—	—	—	—	—	—	—	IR
ICU	IR125	—	—	—	—	—	—	—	IR
ICU	IR126	—	—	—	—	—	—	—	IR
ICU	IR127	—	—	—	—	—	—	—	IR
ICU	IR128	—	—	—	—	—	—	—	IR
ICU	IR129	—	—	—	—	—	—	—	IR
ICU	IR130	—	—	—	—	—	—	—	IR
ICU	IR131	—	—	—	—	—	—	—	IR
ICU	IR132	—	—	—	—	—	—	—	IR
ICU	IR133	—	—	—	—	—	—	—	IR
ICU	IR134	—	—	—	—	—	—	—	IR
ICU	IR135	—	—	—	—	—	—	—	IR
ICU	IR136	—	—	—	—	—	—	—	IR
ICU	IR137	—	—	—	—	—	—	—	IR
ICU	IR138	—	—	—	—	—	—	—	IR
ICU	IR139	—	—	—	—	—	—	—	IR
ICU	IR140	—	—	—	—	—	—	—	IR
ICU	IR141	—	—	—	—	—	—	—	IR
ICU	IR142	—	—	—	—	—	—	—	IR
ICU	IR143	—	—	—	—	—	—	—	IR
ICU	IR144	—	—	—	—	—	—	—	IR
ICU	IR145	—	—	—	—	—	—	—	IR
ICU	IR146	—	—	—	—	—	—	—	IR
ICU	IR149	—	—	—	—	—	—	—	IR
ICU	IR150	—	—	—	—	—	—	—	IR
ICU	IR151	—	—	—	—	—	—	—	IR
ICU	IR152	—	—	—	—	—	—	—	IR
ICU	IR153	—	—	—	—	—	—	—	IR
ICU	IR170	—	—	—	—	—	—	—	IR
ICU	IR171	—	—	—	—	—	—	—	IR
ICU	IR172	—	—	—	—	—	—	—	IR
ICU	IR173	—	—	—	—	—	—	—	IR
ICU	IR174	—	—	—	—	—	—	—	IR
ICU	IR175	—	—	—	—	—	—	—	IR

Table 5.2 List of I/O Registers (Bit Order) (6 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
ICU	IR176	—	—	—	—	—	—	—	IR
ICU	IR177	—	—	—	—	—	—	—	IR
ICU	IR178	—	—	—	—	—	—	—	IR
ICU	IR179	—	—	—	—	—	—	—	IR
ICU	IR180	—	—	—	—	—	—	—	IR
ICU	IR181	—	—	—	—	—	—	—	IR
ICU	IR182	—	—	—	—	—	—	—	IR
ICU	IR183	—	—	—	—	—	—	—	IR
ICU	IR184	—	—	—	—	—	—	—	IR
ICU	IR186	—	—	—	—	—	—	—	IR
ICU	IR187	—	—	—	—	—	—	—	IR
ICU	IR188	—	—	—	—	—	—	—	IR
ICU	IR189	—	—	—	—	—	—	—	IR
ICU	IR190	—	—	—	—	—	—	—	IR
ICU	IR192	—	—	—	—	—	—	—	IR
ICU	IR193	—	—	—	—	—	—	—	IR
ICU	IR194	—	—	—	—	—	—	—	IR
ICU	IR195	—	—	—	—	—	—	—	IR
ICU	IR196	—	—	—	—	—	—	—	IR
ICU	IR214	—	—	—	—	—	—	—	IR
ICU	IR215	—	—	—	—	—	—	—	IR
ICU	IR216	—	—	—	—	—	—	—	IR
ICU	IR217	—	—	—	—	—	—	—	IR
ICU	IR218	—	—	—	—	—	—	—	IR
ICU	IR219	—	—	—	—	—	—	—	IR
ICU	IR220	—	—	—	—	—	—	—	IR
ICU	IR221	—	—	—	—	—	—	—	IR
ICU	IR222	—	—	—	—	—	—	—	IR
ICU	IR223	—	—	—	—	—	—	—	IR
ICU	IR224	—	—	—	—	—	—	—	IR
ICU	IR225	—	—	—	—	—	—	—	IR
ICU	IR246	—	—	—	—	—	—	—	IR
ICU	IR247	—	—	—	—	—	—	—	IR
ICU	IR248	—	—	—	—	—	—	—	IR
ICU	IR249	—	—	—	—	—	—	—	IR
ICU	IR254	—	—	—	—	—	—	—	IR
ICU	DTCER027	—	—	—	—	—	—	—	DTCE
ICU	DTCER028	—	—	—	—	—	—	—	DTCE
ICU	DTCER029	—	—	—	—	—	—	—	DTCE
ICU	DTCER030	—	—	—	—	—	—	—	DTCE
ICU	DTCER031	—	—	—	—	—	—	—	DTCE
ICU	DTCER045	—	—	—	—	—	—	—	DTCE
ICU	DTCER046	—	—	—	—	—	—	—	DTCE
ICU	DTCER064	—	—	—	—	—	—	—	DTCE
ICU	DTCER065	—	—	—	—	—	—	—	DTCE

Table 5.2 List of I/O Registers (Bit Order) (7 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
ICU	DTCER066	—	—	—	—	—	—	—	DTCE
ICU	DTCER067	—	—	—	—	—	—	—	DTCE
ICU	DTCER068	—	—	—	—	—	—	—	DTCE
ICU	DTCER069	—	—	—	—	—	—	—	DTCE
ICU	DTCER070	—	—	—	—	—	—	—	DTCE
ICU	DTCER071	—	—	—	—	—	—	—	DTCE
ICU	DTCER098	—	—	—	—	—	—	—	DTCE
ICU	DTCER102	—	—	—	—	—	—	—	DTCE
ICU	DTCER103	—	—	—	—	—	—	—	DTCE
ICU	DTCER106	—	—	—	—	—	—	—	DTCE
ICU	DTCER114	—	—	—	—	—	—	—	DTCE
ICU	DTCER115	—	—	—	—	—	—	—	DTCE
ICU	DTCER116	—	—	—	—	—	—	—	DTCE
ICU	DTCER117	—	—	—	—	—	—	—	DTCE
ICU	DTCER121	—	—	—	—	—	—	—	DTCE
ICU	DTCER122	—	—	—	—	—	—	—	DTCE
ICU	DTCER125	—	—	—	—	—	—	—	DTCE
ICU	DTCER126	—	—	—	—	—	—	—	DTCE
ICU	DTCER129	—	—	—	—	—	—	—	DTCE
ICU	DTCER130	—	—	—	—	—	—	—	DTCE
ICU	DTCER131	—	—	—	—	—	—	—	DTCE
ICU	DTCER132	—	—	—	—	—	—	—	DTCE
ICU	DTCER134	—	—	—	—	—	—	—	DTCE
ICU	DTCER135	—	—	—	—	—	—	—	DTCE
ICU	DTCER136	—	—	—	—	—	—	—	DTCE
ICU	DTCER137	—	—	—	—	—	—	—	DTCE
ICU	DTCER138	—	—	—	—	—	—	—	DTCE
ICU	DTCER139	—	—	—	—	—	—	—	DTCE
ICU	DTCER140	—	—	—	—	—	—	—	DTCE
ICU	DTCER141	—	—	—	—	—	—	—	DTCE
ICU	DTCER142	—	—	—	—	—	—	—	DTCE
ICU	DTCER143	—	—	—	—	—	—	—	DTCE
ICU	DTCER144	—	—	—	—	—	—	—	DTCE
ICU	DTCER145	—	—	—	—	—	—	—	DTCE
ICU	DTCER149	—	—	—	—	—	—	—	DTCE
ICU	DTCER150	—	—	—	—	—	—	—	DTCE
ICU	DTCER151	—	—	—	—	—	—	—	DTCE
ICU	DTCER152	—	—	—	—	—	—	—	DTCE
ICU	DTCER153	—	—	—	—	—	—	—	DTCE
ICU	DTCER174	—	—	—	—	—	—	—	DTCE
ICU	DTCER175	—	—	—	—	—	—	—	DTCE
ICU	DTCER176	—	—	—	—	—	—	—	DTCE
ICU	DTCER177	—	—	—	—	—	—	—	DTCE
ICU	DTCER178	—	—	—	—	—	—	—	DTCE
ICU	DTCER179	—	—	—	—	—	—	—	DTCE

Table 5.2 List of I/O Registers (Bit Order) (8 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
ICU	DTCER180	—	—	—	—	—	—	—	DTCE
ICU	DTCER181	—	—	—	—	—	—	—	DTCE
ICU	DTCER182	—	—	—	—	—	—	—	DTCE
ICU	DTCER183	—	—	—	—	—	—	—	DTCE
ICU	DTCER184	—	—	—	—	—	—	—	DTCE
ICU	DTCER186	—	—	—	—	—	—	—	DTCE
ICU	DTCER187	—	—	—	—	—	—	—	DTCE
ICU	DTCER188	—	—	—	—	—	—	—	DTCE
ICU	DTCER189	—	—	—	—	—	—	—	DTCE
ICU	DTCER190	—	—	—	—	—	—	—	DTCE
ICU	DTCER192	—	—	—	—	—	—	—	DTCE
ICU	DTCER193	—	—	—	—	—	—	—	DTCE
ICU	DTCER194	—	—	—	—	—	—	—	DTCE
ICU	DTCER195	—	—	—	—	—	—	—	DTCE
ICU	DTCER196	—	—	—	—	—	—	—	DTCE
ICU	DTCER215	—	—	—	—	—	—	—	DTCE
ICU	DTCER216	—	—	—	—	—	—	—	DTCE
ICU	DTCER219	—	—	—	—	—	—	—	DTCE
ICU	DTCER220	—	—	—	—	—	—	—	DTCE
ICU	DTCER223	—	—	—	—	—	—	—	DTCE
ICU	DTCER224	—	—	—	—	—	—	—	DTCE
ICU	DTCER247	—	—	—	—	—	—	—	DTCE
ICU	DTCER248	—	—	—	—	—	—	—	DTCE
ICU	DTCER254	—	—	—	—	—	—	—	DTCE
ICU	IER02	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER03	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER05	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER07	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER08	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER0C	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER0D	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER0E	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER0F	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER10	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER11	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER12	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER13	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER15	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER16	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER17	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER18	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER1A	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER1B	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER1C	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER1E	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0

Table 5.2 List of I/O Registers (Bit Order) (9 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
ICU	IER1F	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	SWINTR	—	—	—	—	—	—	—	SWINT
ICU	FIR	FIEN	—	—	—	—	—	—	—
		FVCT[7:0]							
ICU	IPR00	—	—	—	—	IPR[3:0]			
ICU	IPR01	—	—	—	—	IPR[3:0]			
ICU	IPR02	—	—	—	—	IPR[3:0]			
ICU	IPR03	—	—	—	—	IPR[3:0]			
ICU	IPR04	—	—	—	—	IPR[3:0]			
ICU	IPR05	—	—	—	—	IPR[3:0]			
ICU	IPR06	—	—	—	—	IPR[3:0]			
ICU	IPR07	—	—	—	—	IPR[3:0]			
ICU	IPR14	—	—	—	—	IPR[3:0]			
ICU	IPR18	—	—	—	—	IPR[3:0]			
ICU	IPR20	—	—	—	—	IPR[3:0]			
ICU	IPR21	—	—	—	—	IPR[3:0]			
ICU	IPR22	—	—	—	—	IPR[3:0]			
ICU	IPR23	—	—	—	—	IPR[3:0]			
ICU	IPR24	—	—	—	—	IPR[3:0]			
ICU	IPR25	—	—	—	—	IPR[3:0]			
ICU	IPR26	—	—	—	—	IPR[3:0]			
ICU	IPR27	—	—	—	—	IPR[3:0]			
ICU	IPR40	—	—	—	—	IPR[3:0]			
ICU	IPR44	—	—	—	—	IPR[3:0]			
ICU	IPR48	—	—	—	—	IPR[3:0]			
ICU	IPR49	—	—	—	—	IPR[3:0]			
ICU	IPR51	—	—	—	—	IPR[3:0]			
ICU	IPR52	—	—	—	—	IPR[3:0]			
ICU	IPR53	—	—	—	—	IPR[3:0]			
ICU	IPR54	—	—	—	—	IPR[3:0]			
ICU	IPR55	—	—	—	—	IPR[3:0]			
ICU	IPR56	—	—	—	—	IPR[3:0]			
ICU	IPR57	—	—	—	—	IPR[3:0]			
ICU	IPR58	—	—	—	—	IPR[3:0]			
ICU	IPR59	—	—	—	—	IPR[3:0]			
ICU	IPR5A	—	—	—	—	IPR[3:0]			
ICU	IPR5B	—	—	—	—	IPR[3:0]			
ICU	IPR5C	—	—	—	—	IPR[3:0]			
ICU	IPR5D	—	—	—	—	IPR[3:0]			
ICU	IPR5E	—	—	—	—	IPR[3:0]			
ICU	IPR5F	—	—	—	—	IPR[3:0]			
ICU	IPR60	—	—	—	—	IPR[3:0]			
ICU	IPR67	—	—	—	—	IPR[3:0]			
ICU	IPR68	—	—	—	—	IPR[3:0]			
ICU	IPR69	—	—	—	—	IPR[3:0]			

Table 5.2 List of I/O Registers (Bit Order) (10 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
ICU	IPR6A	—	—	—	—	IPR[3:0]			
ICU	IPR6B	—	—	—	—	IPR[3:0]			
ICU	IPR6C	—	—	—	—	IPR[3:0]			
ICU	IPR6D	—	—	—	—	IPR[3:0]			
ICU	IPR6E	—	—	—	—	IPR[3:0]			
ICU	IPR6F	—	—	—	—	IPR[3:0]			
ICU	IPR80	—	—	—	—	IPR[3:0]			
ICU	IPR81	—	—	—	—	IPR[3:0]			
ICU	IPR82	—	—	—	—	IPR[3:0]			
ICU	IPR88	—	—	—	—	IPR[3:0]			
ICU	IPR89	—	—	—	—	IPR[3:0]			
ICU	IPR8A	—	—	—	—	IPR[3:0]			
ICU	IPR8B	—	—	—	—	IPR[3:0]			
ICU	IPR90	—	—	—	—	IPR[3:0]			
ICU	IRQCR0	—	—	—	—	IRQMD[1:0]		—	—
ICU	IRQCR1	—	—	—	—	IRQMD[1:0]		—	—
ICU	IRQCR2	—	—	—	—	IRQMD[1:0]		—	—
ICU	IRQCR3	—	—	—	—	IRQMD[1:0]		—	—
ICU	IRQCR4	—	—	—	—	IRQMD[1:0]		—	—
ICU	IRQCR5	—	—	—	—	IRQMD[1:0]		—	—
ICU	IRQCR6	—	—	—	—	IRQMD[1:0]		—	—
ICU	IRQCR7	—	—	—	—	IRQMD[1:0]		—	—
ICU	NMISR	—	—	—	—	—	OSTST	LVDST	NMIST
ICU	NMIER	—	—	—	—	—	OSTEN	LVDEN	NMIEN
ICU	NMICLR	—	—	—	—	—	OSTCLR	—	NMICLR
ICU	NMICR	—	—	—	—	NMIMD	—	—	—
CMT	CMSTR0	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	STR1	STR0
CMT0	CMCR	—	—	—	—	—	—	—	—
		—	CMIE	—	—	—	—	CKS[1:0]	
CMT0	CMCNT								
CMT0	CMCOR								
CMT1	CMCR	—	—	—	—	—	—	—	—
		—	CMIE	—	—	—	—	CKS[1:0]	
CMT1	CMCNT								
CMT1	CMCOR								
CMT	CMSTR1	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	STR3	STR2
CMT2	CMCR	—	—	—	—	—	—	—	—
		—	CMIE	—	—	—	—	CKS[1:0]	

Table 5.2 List of I/O Registers (Bit Order) (11 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
CMT2	CMCNT								
CMT2	CMCOR								
CMT3	CMCR	—	—	—	—	—	—	—	—
		—	CMIE	—	—	—	—	CKS[1:0]	
CMT3	CMCNT								
CMT3	CMCOR								
WDT	TCSR	—	TMS	TME	—	—	CKS[2:0]		
WDT	WINA								
WDT	TCNT								
WDT	WINB								
WDT	RSTCSR	WOVF	RSTE	—	—	—	—	—	—
IWDT	IWDTCR	—	—	—	—	—	—	—	—
		CKS[3:0]				—	—	TOPS[1:0]	
IWDT	IWDTSR	—	UNDFF	CNTVAL[13:0]					
		CNTVAL[13:0]							
AD0	ADDRA*1	—	—	—	—	—	—		
AD0	ADDRB*1	—	—	—	—	—	—		
AD0	ADDRC*1	—	—	—	—	—	—		
AD0	ADDRD*1	—	—	—	—	—	—		
AD0	ADDRE*1	—	—	—	—	—	—		
AD0	ADDRF*1	—	—	—	—	—	—		
AD0	ADDRG*1	—	—	—	—	—	—		
AD0	ADDRH*1	—	—	—	—	—	—		
AD0	ADCSR	—	ADIE	ADST	—	CH[3:0]			
AD0	ADCR	—	—	—	—	CKS[1:0]		MODE[1:0]	
AD0	ADSSTR								
AD0	ADDIAGR	—	—	—	—	—	—	DIAG[1:0]	
AD0	ADDRI*1	—	—	—	—	—	—		
AD0	ADDRJ*1	—	—	—	—	—	—		

Table 5.2 List of I/O Registers (Bit Order) (12 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
AD0	ADDRK *1	—	—	—	—	—	—		
AD0	ADDRL*1	—	—	—	—	—	—		
AD0	ADSTRGR	—	—	—	ADSTRS[4:0]				
AD0	ADDPR	DPSEL	—	—	—	—	—	—	DPPRC
SCI0	SMR	CM	CHR	PE	PM	STOP	MP	CKS[1:0]	
SCI0	BRR								
SCI0	SCR	TIE	RIE	TE	RE	MPIE	TEIE	CKE[1:0]	
SCI0	TDR								
SCI0	SSR	TDRE	RDRF	ORER	FER	PER	TEND	MPB	MPBT
SCI0	RDR								
SCI0	SCMR	BCP2	—	—	—	SDIR	SINV	—	SMIF
SCI0	SEMR	—	—	NFEN	ABCS	—	—	—	—
SMCI0	SMR	GM	BLK	PE	PM	(BCP[1:0])		CKS[1:0]	
SMCI0	BRR								
SMCI0	SCR	TIE	RIE	TE	RE	MPIE	TEIE	CKE[1:0]	
SMCI0	TDR								
SMCI0	SSR	TDRE	RDRF	ORER	ERS	PER	TEND	MPB	MPBT
SMCI0	RDR								
SMCI0	SCMR	BCP2	—	—	—	SDIR	SINV	—	SMIF
SCI1	SMR	CM	CHR	PE	PM	STOP	MP	CKS[1:0]	
SCI1	BRR								
SCI1	SCR	TIE	RIE	TE	RE	MPIE	TEIE	CKE[1:0]	
SCI1	TDR								
SCI1	SSR	TDRE	RDRF	ORER	FER	PER	TEND	MPB	MPBT
SCI1	RDR								
SCI1	SCMR	BCP2	—	—	—	SDIR	SINV	—	SMIF
SCI1	SEMR	—	—	NFEN	ABCS	—	—	—	—
SMCI1	SMR	GM	BLK	PE	PM	(BCP[1:0])		CKS[1:0]	
SMCI1	BRR								
SMCI1	SCR	TIE	RIE	TE	RE	MPIE	TEIE	CKE[1:0]	
SMCI1	TDR								
SMCI1	SSR	TDRE	RDRF	ORER	ERS	PER	TEND	MPB	MPBT
SMCI1	RDR								
SMCI1	SCMR	BCP2	—	—	—	SDIR	SINV	—	SMIF
SCI2	SMR	CM	CHR	PE	PM	STOP	MP	CKS[1:0]	
SCI2	BRR								
SCI2	SCR	TIE	RIE	TE	RE	MPIE	TEIE	CKE[1:0]	
SCI2	TDR								
SCI2	SSR	TDRE	RDRF	ORER	FER	PER	TEND	MPB	MPBT
SCI2	RDR								
SCI2	SCMR	BCP2	—	—	—	SDIR	SINV	—	SMIF
SMCI2	SMR	GM	BLK	PE	PM	(BCP[1:0])		CKS[1:0]	
SMCI2	BRR								

Table 5.2 List of I/O Registers (Bit Order) (13 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
SMCI2	SCR	TIE	RIE	TE	RE	MPIE	TEIE	CKE[1:0]	
SMCI2	TDR								
SMCI2	SSR	TDRE	RDRF	ORER	ERS	PER	TEND	MPB	MPBT
SMCI2	RDR								
SMCI2	SCMR	BCP2	—	—	—	SDIR	SINV	—	SMIF
CRC	CRCCR	DORCLR	—	—	—	—	LMS	GPS[1:0]	
CRC	CRCDIR								
CRC	CRCDOR								
RIIC0	ICCR1	ICE	IICRST	CLO	SOWP	SCLO	SDAO	SCLI	SDAI
RIIC0	ICCR2	BBSY	MST	TRS	—	SP	RS	ST	—
RIIC0	ICMR1	MTWP	CKS[2:0]			BCWP	BC[2:0]		
RIIC0	ICMR2	DLCS	SDDL[2:0]			TMWE	TMOH	TMOL	TMOS
RIIC0	ICMR3	SMBS	WAIT	RDRFS	ACKWP	ACKBT	ACKBR	NF[1:0]	
RIIC0	ICFER	—	SCLE	NFE	NACKE	SALE	NALE	MALE	TMOE
RIIC0	ICSER	HOAE	—	DIDE	—	GCAE	SAR2E	SAR1E	SAR0E
RIIC0	ICIER	TIE	TEIE	RIE	NAKIE	SPIE	STIE	ALIE	TMOIE
RIIC0	ICSR1	HOA	—	DID	—	GCA	AAS2	AAS1	AAS0
RIIC0	ICSR2	TDRE	TEND	RDRF	NACKF	STOP	START	AL	TMOF
RIIC0	SARL0	SVA[6:0]							SVA0
RIIC0	TMOCNTL								
RIIC0	SARU0	—	—	—	—	—	SVA[1:0]		FS
RIIC0	TMOCNTU								
RIIC0	SARU1	—	—	—	—	—	SVA[1:0]		FS
RIIC0	SARL1	SVA[6:0]							SVA0
RIIC0	SARL2	SVA[6:0]							SVA0
RIIC0	SARU2	—	—	—	—	—	SVA[1:0]		FS
RIIC0	ICBRL	—	—	—	BRL[4:0]				
RIIC0	ICBRH	—	—	—	BRH[4:0]				
RIIC0	ICDRT								
RIIC0	ICDRR								
RSPI0	SPCR	SPRIE	SPE	SPTIE	SPEIE	MSTR	MODFEN	TXMD	SPMS
RSPI0	SSLP	—	—	—	—	SSLP3	SSLP2	SSLP1	SSLP0
RSPI0	SPPCR	—	—	MOIFE	MOIFV	—	—	SPLP2	SPLP
RSPI0	SPSR	SPRF	—	SPTEF	—	PERF	MODF	IDLNF	OVRF
RSPI0	SPDR	H[15:0]							
		H[15:0]							
		L[15:0]							
		L[15:0]							
RSPI0	SPSCR	—	—	—	—	—	SPSLN[2:0]		
RSPI0	SPSSR	—	SPECM[2:0]			—	SPCP[2:0]		
RSPI0	SPBR	SPR7	SPR6	SPR5	SPR4	SPR3	SPR2	SPR1	SPR0
RSPI0	SPDCR	—	—	SPLW	SPRDTD	SLSEL[1:0]		SPFC[1:0]	

Table 5.2 List of I/O Registers (Bit Order) (14 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
RSPI0	SPCKD	—	—	—	—	—	SCKDL[2:0]		
RSPI0	SSLND	—	—	—	—	—	SLNDL[2:0]		
RSPI0	SPND	—	—	—	—	—	SPNDL[2:0]		
RSPI0	SPCR2	—	—	—	—	PTE	SPIIE	SPOE	SPPE
RSPI0	SPCMD0	SCKDEN	SLNDEN	SPNDEN	LSBF	SPB[3:0]			
		SSLKP	SSLA[2:0]			BRDV[1:0]		CPOL	CPHA
RSPI0	SPCMD1	SCKDEN	SLNDEN	SPNDEN	LSBF	SPB[3:0]			
		SSLKP	SSLA[2:0]			BRDV[1:0]		CPOL	CPHA
RSPI0	SPCMD2	SCKDEN	SLNDEN	SPNDEN	LSBF	SPB[3:0]			
		SSLKP	SSLA[2:0]			BRDV[1:0]		CPOL	CPHA
RSPI0	SPCMD3	SCKDEN	SLNDEN	SPNDEN	LSBF	SPB[3:0]			
		SSLKP	SSLA[2:0]			BRDV[1:0]		CPOL	CPHA
RSPI0	SPCMD4	SCKDEN	SLNDEN	SPNDEN	LSBF	SPB[3:0]			
		SSLKP	SSLA[2:0]			BRDV[1:0]		CPOL	CPHA
RSPI0	SPCMD5	SCKDEN	SLNDEN	SPNDEN	LSBF	SPB[3:0]			
		SSLKP	SSLA[2:0]			BRDV[1:0]		CPOL	CPHA
RSPI0	SPCMD6	SCKDEN	SLNDEN	SPNDEN	LSBF	SPB[3:0]			
		SSLKP	SSLA[2:0]			BRDV[1:0]		CPOL	CPHA
RSPI0	SPCMD7	SCKDEN	SLNDEN	SPNDEN	LSBF	SPB[3:0]			
		SSLKP	SSLA[2:0]			BRDV[1:0]		CPOL	CPHA
S12AD0	ADCSR	ADST	ADCS[1:0]		ADIE	CKS[1:0]		TRGE	EXTRG
S12AD0	ADANS	—	—	CH[1:0]		—	PG002SEL	PG001SEL	PG000SEL
		—	—	—	—	—	PG002EN	PG001EN	PG000EN
S12AD0	ADPG	—	—	—	—	PG002GAIN[3:0]			
		PG001GAIN[3:0]				PG000GAIN[3:0]			
S12AD0	ADCER	ADRFMT	—	ADIEW	ADIE2	DIAGM	DIAGLD	DIAGVAL[1:0]	
		—	—	ACE	—	—	ADPRC[1:0]		SHBYP
S12AD0	ADSTRGR	—	—	—	ADSTRS1[4:0]				
		—	—	—	ADSTRS0[4:0]				
S12AD	ADCMPMD0	—	—	CEN102[1:0]		CEN101[1:0]		CEN100[1:0]	
		—	—	CEN002[1:0]		CEN001[1:0]		CEN000[1:0]	
S12AD	ADCMPMD1	—	VSELL1	VSELH1	CSEL1	—	VSELL0	VSELH0	CSEL0
		—	REFH[2:0]			—	REFL[2:0]		
S12AD	ADCMPNR0	—	—	—	—	C002NR[3:0]			
		C001NR[3:0]				C000NR[3:0]			
S12AD	ADCMPNR1	—	—	—	—	C102NR[3:0]			
		C101NR[3:0]				C100NR[3:0]			
S12AD	ADCMPFR	—	—	C102FLAG	C101FLAG	C100FLAG	C002FLAG	C001FLAG	C000FLAG
S12AD	ADCMPSEL	—	—	—	—	—	—	POERQ	IE
		—	—	SEL102	SEL101	SEL100	SEL002	SEL001	SEL000
S12AD0	ADRD*2	DIAGST[1:0]		—	—	AD11	AD10	AD9	AD8
		AD7	AD6	AD5	AD4	AD3	AD2	AD1	AD0
S12AD0	ADDR0A*2	—	—	—	—	AD11	AD10	AD9	AD8
		AD7	AD6	AD5	AD4	AD3	AD2	AD1	AD0

Table 5.2 List of I/O Registers (Bit Order) (15 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
S12AD0	ADDR1*2	—	—	—	—	AD11	AD10	AD9	AD8
		AD7	AD6	AD5	AD4	AD3	AD2	AD1	AD0
S12AD0	ADDR2*2	—	—	—	—	AD11	AD10	AD9	AD8
		AD7	AD6	AD5	AD4	AD3	AD2	AD1	AD0
S12AD0	ADDR3*2	—	—	—	—	AD11	AD10	AD9	AD8
		AD7	AD6	AD5	AD4	AD3	AD2	AD1	AD0
S12AD0	ADDR0B*2	—	—	—	—	AD11	AD10	AD9	AD8
		AD7	AD6	AD5	AD4	AD3	AD2	AD1	AD0
S12AD0	ADSSTR								
S12AD1	ADCSR	ADST	ADCS[1:0]		ADIE	CKS[1:0]		TRGE	EXTRG
S12AD1	ADANS	—	—	CH[1:0]		—	PG102SEL	PG101SEL	PG100SEL
		—	—	—	—	—	PG102EN	PG101EN	PG100EN
S12AD1	ADPG	—	—	—	—	PG102GAIN[3:0]			
		PG101GAIN[3:0]				PG100GAIN[3:0]			
S12AD1	ADCER	ADRFMT	—	ADIEW	ADIE2	DIAGM	DIAGLD	DIAGVAL[1:0]	
		—	—	ACE	—	—	ADPRC[1:0]		SHBYP
S12AD1	ADSTRGR	—	—	—	ADSTRS1[4:0]				
		—	—	—	ADSTRS0[4:0]				
S12AD1	ADRD*2	DIAGST[1:0]		—	—	AD11	AD10	AD9	AD8
		AD7	AD6	AD5	AD4	AD3	AD2	AD1	AD0
S12AD1	ADDR0A*2	—	—	—	—	AD11	AD10	AD9	AD8
		AD7	AD6	AD5	AD4	AD3	AD2	AD1	AD0
S12AD1	ADDR1*2	—	—	—	—	AD11	AD10	AD9	AD8
		AD7	AD6	AD5	AD4	AD3	AD2	AD1	AD0
S12AD1	ADDR2*2	—	—	—	—	AD11	AD10	AD9	AD8
		AD7	AD6	AD5	AD4	AD3	AD2	AD1	AD0
S12AD1	ADDR3*2	—	—	—	—	AD11	AD10	AD9	AD8
		AD7	AD6	AD5	AD4	AD3	AD2	AD1	AD0
S12AD1	ADDR0B*2	—	—	—	—	AD11	AD10	AD9	AD8
		AD7	AD6	AD5	AD4	AD3	AD2	AD1	AD0
S12AD1	ADSSTR								
PORT1	DDR	—	—	—	—	—	—	B1	B0
PORT2	DDR	—	—	—	B4	B3	B2	B1	B0
PORT3	DDR	—	—	—	—	B3	B2	B1	B0
PORT7	DDR	—	B6	B5	B4	B3	B2	B1	B0
PORT8	DDR	—	—	—	—	—	B2	B1	B0
PORT9	DDR	—	B6	B5	B4	B3	B2	B1	B0
PORTA	DDR	—	—	B5	B4	B3	B2	B1	B0
PORTB	DDR	B7	B6	B5	B4	B3	B2	B1	B0
PORTD	DDR	B7	B6	B5	B4	B3	B2	B1	B0
PORTE	DDR	—	—	B5	B4	B3	—	B1	B0
PORTG	DDR	—	—	B5	B4	B3	B2	B1	B0
PORT1	DR	—	—	—	—	—	—	B1	B0
PORT2	DR	—	—	—	B4	B3	B2	B1	B0
PORT3	DR	—	—	—	—	B3	B2	B1	B0

Table 5.2 List of I/O Registers (Bit Order) (16 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
PORT7	DR	—	B6	B5	B4	B3	B2	B1	B0
PORT8	DR	—	—	—	—	—	B2	B1	B0
PORT9	DR	—	B6	B5	B4	B3	B2	B1	B0
PORTA	DR	—	—	B5	B4	B3	B2	B1	B0
PORTB	DR	B7	B6	B5	B4	B3	B2	B1	B0
PORTD	DR	B7	B6	B5	B4	B3	B2	B1	B0
PORTE	DR	—	—	B5	B4	B3	—	B1	B0
PORTG	DR	—	—	B5	B4	B3	B2	B1	B0
PORT1	PORT	—	—	—	—	—	—	B1	B0
PORT2	PORT	—	—	—	B4	B3	B2	B1	B0
PORT3	PORT	—	—	—	—	B3	B2	B1	B0
PORT4	PORT	B7	B6	B5	B4	B3	B2	B1	B0
PORT5	PORT	—	—	B5	B4	B3	B2	B1	B0
PORT6	PORT	—	—	B5	B4	B3	B2	B1	B0
PORT7	PORT	—	B6	B5	B4	B3	B2	B1	B0
PORT8	PORT	—	—	—	—	—	B2	B1	B0
PORT9	PORT	—	B6	B5	B4	B3	B2	B1	B0
PORTA	PORT	—	—	B5	B4	B3	B2	B1	B0
PORTB	PORT	B7	B6	B5	B4	B3	B2	B1	B0
PORTD	PORT	B7	B6	B5	B4	B3	B2	B1	B0
PORTE	PORT	—	—	B5	B4	B3	B2	B1	B0
PORTG	PORT	—	—	B5	B4	B3	B2	B1	B0
PORT1	ICR	—	—	—	—	—	—	B1	B0
PORT2	ICR	—	—	—	B4	B3	B2	B1	B0
PORT3	ICR	—	—	—	—	B3	B2	B1	B0
PORT4	ICR	B7	B6	B5	B4	B3	B2	B1	B0
PORT5	ICR	—	—	B5	B4	B3	B2	B1	B0
PORT6	ICR	—	—	B5	B4	B3	B2	B1	B0
PORT7	ICR	—	B6	B5	B4	B3	B2	B1	B0
PORT8	ICR	—	—	—	—	—	B2	B1	B0
PORT9	ICR	—	B6	B5	B4	B3	B2	B1	B0
PORTA	ICR	—	—	B5	B4	B3	B2	B1	B0
PORTB	ICR	B7	B6	B5	B4	B3	B2	B1	B0
PORTD	ICR	B7	B6	B5	B4	B3	B2	B1	B0
PORTE	ICR	—	—	B5	B4	B3	—	B1	B0
PORTG	ICR	—	—	B5	B4	B3	B2	B1	B0
IOPORT	PF8IRQ	—	—	—	—	ITS1[1:0]		ITS0[1:0]	
IOPORT	PF9IRQ	—	—	—	—	—	ITS2	—	—
IOPORT	PFAADC	—	—	—	—	—	—	ADTRG1S	ADTRG0S
IOPORT	PFCMTU	TCLKS[1:0]		—	—	—	—	MTUS1	MTUS0
IOPORT	PFDGPT	—	—	—	—	—	—	—	GPTS
IOPORT	PFFSCI	—	—	—	—	—	SCI2S	—	—
IOPORT	PFGSPI	SSL3E	SSL2E	SSL1E	SSL0E	MISOE	MOSIE	RSPCKE	—
IOPORT	PFHSPI	—	—	—	—	—	—	RSPIS[1:0]	
IOPORT	PFJCAN	CANS[1:0]		—	—	—	—	—	CANE

Table 5.2 List of I/O Registers (Bit Order) (17 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
IOPORT	PFKLIN	—	—	—	—	—	—	—	LINE
IOPORT	PFMPOE	—	—	—	POE11E	POE10E	POE8E	POE4E	POE0E
IOPORT	PFNPOE	POE10S	—	—	—	—	—	—	—
SYSTEM	DPSBYCR	DPSBY	IOKEEP	—	—	—	—	—	—
SYSTEM	DPSWCR	—	—	WTSTS[5:0]					
SYSTEM	DPSIER	DNMIE	—	—	DLVDE	—	—	DIRQ1E	DIRQ0E
SYSTEM	DPSIFR	DNMIF	—	—	DLVDF	—	—	DIRQ1F	DIRQ0F
SYSTEM	DPSIEGR	DNMIEG	—	—	—	—	—	DIRQ1EG	DIRQ0EG
SYSTEM	RSTSR	DPSRSTF	—	—	—	—	LVD2F	LVD1F	PORF
FLASH	FWEPROR	—	—	—	—	—	—	FLWE[1:0]	
SYSTEM	LVDKEYR	KEY[7:0]							
SYSTEM	LVDCR	LVD2E	LVD2RI	—	—	LVD1E	LVD1RI	—	—
SYSTEM	DPSBKR0								
SYSTEM	DPSBKR1								
SYSTEM	DPSBKR2								
SYSTEM	DPSBKR3								
SYSTEM	DPSBKR4								
SYSTEM	DPSBKR5								
SYSTEM	DPSBKR6								
SYSTEM	DPSBKR7								
SYSTEM	DPSBKR8								
SYSTEM	DPSBKR9								
SYSTEM	DPSBKR10								
SYSTEM	DPSBKR11								
SYSTEM	DPSBKR12								
SYSTEM	DPSBKR13								
SYSTEM	DPSBKR14								
SYSTEM	DPSBKR15								
SYSTEM	DPSBKR16								
SYSTEM	DPSBKR17								
SYSTEM	DPSBKR18								
SYSTEM	DPSBKR19								
SYSTEM	DPSBKR20								
SYSTEM	DPSBKR21								
SYSTEM	DPSBKR22								
SYSTEM	DPSBKR23								
SYSTEM	DPSBKR24								
SYSTEM	DPSBKR25								
SYSTEM	DPSBKR26								
SYSTEM	DPSBKR27								
SYSTEM	DPSBKR28								
SYSTEM	DPSBKR29								
SYSTEM	DPSBKR30								
SYSTEM	DPSBKR31								

Table 5.2 List of I/O Registers (Bit Order) (18 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
POE	ICSR1	—	—	—	POE0F	—	—	—	PIE1
		—	—	—	—	—	—	POE0M[1:0]	
POE	OCSR1	OSF1	—	—	—	—	—	OCE1	OIE1
		—	—	—	—	—	—	—	—
POE	ICSR2	—	—	—	POE4F	—	—	—	PIE2
		—	—	—	—	—	—	POE4M[1:0]	
POE	OCSR2	OSF2	—	—	—	—	—	OCE2	OIE2
		—	—	—	—	—	—	—	—
POE	ICSR3	—	—	—	POE8F	—	—	POE8E	PIE3
		—	—	—	—	—	—	POE8M[1:0]	
POE	SPOER	—	—	—	GPT23HIZ	GPT01HIZ	MTUCH0HIZ	MTUCH67HIZ	MTUCH34HIZ
POE	POECR1	—	—	—	—	MTU0DZE	MTU0CZE	MTU0BZE	MTU0AZE
POE	POECR2	—	—	—	—	—	MTU3BDZE	MTU4ACZE	MTU4BDZE
		—	—	—	—	—	MTU6BDZE	MTU7ACZE	MTU7BDZE
POE	POECR3	—	—	—	—	—	—	GPT3ABZE	GPT2ABZE
		—	—	—	—	—	—	GPT1ABZE	GPT0ABZE
POE	POECR4	—	—	IC5ADDMT67ZE	IC4ADDMT67ZE	IC3ADDMT67ZE	—	IC1ADDMT67ZE	CMADDMT67ZE
		—	—	IC5ADDMT34ZE	IC4ADDMT34ZE	IC3ADDMT34ZE	IC2ADDMT34ZE	—	CMADDMT34ZE
POE	POECR5	—	—	—	—	—	—	—	—
		—	—	IC5ADDMT0ZE	IC4ADDMT0ZE	—	IC2ADDMT0ZE	IC1ADDMT0ZE	CMADDMT0ZE
POE	POECR6	—	—	—	IC4ADDGPT23ZE	IC3ADDGPT23ZE	IC2ADDGPT23ZE	IC1ADDGPT23ZE	CMADDGPT23ZE
		—	—	IC5ADDGPT01ZE	—	IC3ADDGPT01ZE	IC2ADDGPT01ZE	IC1ADDGPT01ZE	CMADDGPT01ZE
POE	ICSR4	—	—	—	POE10F	—	—	POE10E	PIE4
		—	—	—	—	—	—	POE10M[1:0]	
POE	ALR1	—	—	—	—	—	—	—	—
		OLSEN	—	OLSG2B	OLSG2A	OLSG1B	OLSG1A	OLSG0B	OLSG0A
POE	ICSR5	—	—	—	POE11F	—	—	POE11E	PIE5
		—	—	—	—	—	—	POE11M[1:0]	
CAN0*3	MB.ID	IDE	RTR	—	SID[10:0]				
		SID[10:0]					EID[17:0]		
		EID[17:0]							
		EID[17:0]							
	MB.DLC	—	—	—	—	—	—	—	—
		—	—	—	—	DLC[3:0]			
	MB.DATA 0 to 7								
	MB.TS	TSH[7:0]							
		TSL[7:0]							
CAN0*3	MKR0	—	—	—	SID[10:0]				
		SID[10:0]						EID[17 0]	
		EID[17:0]							
		EID[17:0]							

Table 5.2 List of I/O Registers (Bit Order) (19 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
CAN0*3	MKR1	—	—	—	SID[10:0]				
		SID[10:0]						EID[17 0]	
		EID[17:0]							
		EID[17:0]							
CAN0*3	MKR2	—	—	—	SID[10:0]				
		SID[10:0]						EID[17 0]	
		EID[17:0]							
		EID[17:0]							
CAN0*3	MKR3	—	—	—	SID[10:0]				
		SID[10:0]						EID[17 0]	
		EID[17:0]							
		EID[17:0]							
CAN0*3	MKR4	—	—	—	SID[10:0]				
		SID[10:0]						EID[17 0]	
		EID[17:0]							
		EID[17:0]							
CAN0*3	MKR5	—	—	—	SID[10:0]				
		SID[10:0]						EID[17 0]	
		EID[17:0]							
		EID[17:0]							
CAN0*3	MKR6	—	—	—	SID[10:0]				
		SID[10:0]						EID[17 0]	
		EID[17:0]							
		EID[17:0]							
CAN0*3	MKR7	—	—	—	SID[10:0]				
		SID[10:0]						EID[17 0]	
		EID[17:0]							
		EID[17:0]							
CAN0*3	FIDCR0	IDE	RTR	—	SID[10:0]				
		SID[10:0]						EID[17:0]	
		EID[17:0]							
		EID[17:0]							
CAN0*3	FIDCR1	IDE	RTR	—	SID[10:0]				
		SID[10:0]						EID[17:0]	
		EID[17:0]							
		EID[17:0]							
CAN0*3	MKIVLR								
CAN0*3	MIER	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	—

Table 5.2 List of I/O Registers (Bit Order) (20 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
CAN0*3	MCTL.TX	TRMREQ	RECREQ	—	ONESHOT	—	TRMABT	TRMACTIVE	SENTDATA
	MCTL.RX	TRMREQ	RECREQ	—	ONESHOT	—	MSGLOST	INVALDATA	NEWDATA
CAN0*3	CTLR	—	—	RBOC	BOM[1:0]		SLPM	CANM[1:0]	
		TSPS[1:0]		TSRC	TPM	MLM	IDFM[1:0]		MBM
CAN0*3	STR	—	RECST	TRMST	BOST	EPST	SLPST	HLTST	RSTST
		EST	TABST	FMLST	NMLST	TFST	RFST	SDST	NDST
CAN0*3	BCR	TSEG1[3:0]				—	—	BRP[9:0]	
		BRP[9:0]							
		—	—	SJW[1:0]		—	TSEG2[2:0]		
		—	—	—	—	—	—	—	—
CAN0*3	RFCR	RFEST	RFWST	RFFST	RFMLF	RFUST[2:0]			RFE
CAN0*3	RFPCR	—	—	—	—	—	—	—	—
CAN0*3	TFCR	TFEST	TFFST	—	—	TFUST[2:0]			TFE
CAN0*3	TFPCR	—	—	—	—	—	—	—	—
CAN0*3	EIER	BLIE	OLIE	ORIE	BORIE	BOEIE	EPIE	EWIE	BEIE
CAN0*3	EIFR	BLIF	OLIF	ORIF	BORIF	BOEIF	EPIF	EWIF	BEIF
CAN0*3	RECR	—	—	—	—	—	—	—	—
CAN0*3	TECR	—	—	—	—	—	—	—	—
CAN0*3	ECSR	EDPM	ADEF	BE0F	BE1F	CEF	AEF	FEF	SEF
CAN0*3	CSSR	—	—	—	—	—	—	—	—
CAN0*3	MSSR	SEST	—	—	MBNST[4:0]				
CAN0*3	MSMR	—	—	—	—	—	—	MBSM[1:0]	
CAN0*3	TSR	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	—
CAN0*3	AFSR	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	—
CAN0*3	TCR	—	—	—	—	—	TSTM[1:0]		TSTE
LIN0	LWBR	—	—	—	—	—	—	—	LWBR0
LIN0	LBRP0								
LIN0	LBRP1								
LIN0	LSTC								LSTM
LIN0	L0MD	—	—	—	—	LCKS[1:0]		—	—
LIN0	L0BRK	—	—	BDT[1:0]		BLT[3:0]			
LIN0	L0SPC	—	—	IBS[1:0]		—	IBSH[2:0]		
LIN0	L0WUP	WUTL[3:0]				—	—	—	—
LIN0	L0IE	—	—	—	—	—	ERRIE	FRCIE	FTCIE
LIN0	L0EDE	—	—	—	—	FERE	FTERE	PBERE	BERE
LIN0	L0C	—	—	—	—	—	—	OM1	OM0
LIN0	L0TC	—	—	—	—	—	—	RTS	FTS
LIN0	L0MST	—	—	—	—	—	—	OMM1	OMM0
LIN0	L0ST	HTRC	D1RC	—	—	ERR	—	FRC	FTC
LIN0	L0EST	—	—	CSER	—	FER	FTER	PBER	BER
LIN0	L0RFC	—	FSM	CSM	RFT	RFDL[3:0]			
LIN0	L0IDB	IDP		ID					
LIN0	L0CBR								

Table 5.2 List of I/O Registers (Bit Order) (21 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
LIN0	L0DB1								
LIN0	L0DB2								
LIN0	L0DB3								
LIN0	L0DB4								
LIN0	L0DB5								
LIN0	L0DB6								
LIN0	L0DB7								
LIN0	L0DB8								
MTU3	TCR	CCLR[2:0]			CKEG[1:0]		TPSC[2:0]		
MTU4	TCR	CCLR[2:0]			CKEG[1:0]		TPSC[2:0]		
MTU3	TMDR1	—	—	BFB	BFA	MD[3:0]			
MTU4	TMDR1	—	—	BFB	BFA	MD[3:0]			
MTU3	TIORH	IOB[3:0]				IOA[3:0]			
MTU3	TIORL	IOD[3:0]				IOC[3:0]			
MTU4	TIORH	IOB[3:0]				IOA[3:0]			
MTU4	TIORL	IOD[3:0]				IOC[3:0]			
MTU3	TIER	TTGE	—	—	TCIEV	TGIED	TGIEC	TGIEB	TGIEA
MTU4	TIER	TTGE	TTGE2	—	TCIEV	TGIED	TGIEC	TGIEB	TGIEA
MTU	TOERA	—	—	OE4D	OE4C	OE3D	OE4B	OE4A	OE3B
MTU	TGCRA	—	BDC	N	P	FB	WF	VF	UF
MTU	TOCR1A	—	PSYE	—	—	TOCL	TOCS	OLSN	OLSP
MTU	TOCR2A	BF[1:0]		OLS3N	OLS3P	OLS2N	OLS2P	OLS1N	OLS1P
MTU3	TCNT								
MTU4	TCNT								
MTU	TCDRA								
MTU	TDDRA								
MTU3	TGRA								
MTU3	TGRB								
MTU4	TGRA								
MTU4	TGRB								
MTU	TCNTSA								
MTU	TCBRA								
MTU3	TGRC								

Table 5.2 List of I/O Registers (Bit Order) (22 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
MTU3	TGRD								
MTU4	TGRC								
MTU4	TGRD								
MTU3	TSR	TCFD	—	—	TCFV	TGFD	TGFC	TGFB	TGFA
MTU4	TSR	TCFD	—	—	TCFV	TGFD	TGFC	TGFB	TGFA
MTU	TITCR1A	T3AEN	T3ACOR[2:0]			T4VEN	T4VCOR[2:0]		
MTU	TBTERA	—	T3ACOR[2:0]			—	T4VCNT[2:0]]		
MTU	TBTERA	—	—	—	—	—	—	BTE[1:0]	
MTU	TDERA	—	—	—	—	—	—	—	TDER
MTU	TOLBRA	—	—	OLS3N	OLS3P	OLS2N	OLS2P	OLS1N	OLS1P
MTU3	TBTM	—	—	—	—	—	—	TTSB	TTSA
MTU4	TBTM	—	—	—	—	—	—	TTSB	TTSA
MTU	TITMRA	—	—	—	—	—	—	—	TITM
MTU	TITCR2A	—	—	—	—	—	TRG4COR[2:0]		
MTU	TITCNT2A	—	—	—	—	—	TRG4COR[2:0]		
MTU4	TADCR	BF[1:0]		—	—	—	—	—	—
		UT4AE	DT4AE	UT4BE	DT4BE	ITA3AE	ITA4VE	ITB3AE	ITB4VE
MTU4	TADCORA								
MTU4	TADCORB								
MTU4	TADCOBRA								
MTU4	TADCOBRB								
MTU	TWCRA	CCE	—	—	—	—	—	—	WRE
MTU	TMDR2A	—	—	—	—	—	—	—	DRS
MTU3	TGRE								
MTU4	TGRE								
MTU4	TGRF								
MTU	TSTRA	CST4	CST3	—	—	—	CST2	CST1	CST0
MTU	TSYRA	SYNC4	SYNC3	—	—	—	SYNC2	SYNC1	SYNC0
MTU	TCSYSTR	SCH0	SCH1	SCH2	SCH3	SCH4	—	SCH6	SCH7
MTU	TRWERA	—	—	—	—	—	—	—	RWE
MTU0	TCR	CCLR[2:0]			CKEG[1:0]		TPSC[2:0]		
MTU0	TMDR1	—	BFE	BFB	BFA	MD[3:0]			
MTU0	TIORH	IOB[3:0]				IOA[3:0]			
MTU0	TIORL	IOD[3:0]				IOC[3:0]			
MTU0	TIER	TTEG	—	—	TCIEV	TGIED	TGIEC	TGIEB	TGIEA
MTU0	TSR	—	—	—	TCFV	TGFD	TGFC	TGFB	TGFA
MTU0	TCNT								

Table 5.2 List of I/O Registers (Bit Order) (23 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
MTU0	TGRA								
MTU0	TGRB								
MTU0	TGRC								
MTU0	TGRD								
MTU0	TGRE								
MTU0	TGRF								
MTU0	TIER2	TTGE2	—	—	—	—	—	TGIEF	TGIEE
MTU0	TSR2	—	—	—	—	—	—	TGFF	TGFE
MTU0	TBTM	—	—	—	—	—	TTSE	TTSB	TTSA
MTU1	TCR	—	CCLR[1:0]		CKEG[1:0]		TPSC[2:0]		
MTU1	TMDR1	—	—	—	—	MD[3:0]			
MTU1	TIOR	IOB[3:0]				IOA[3:0]			
MTU1	TIER	TTEG	—	TCIEU	TCIEV	—	—	TGIEB	TGIEA
MTU1	TSR	TCFD	—	TCFU	TCFV	—	—	TGFB	TGFA
MTU1	TCNT								
MTU1	TGRA								
MTU1	TGRB								
MTU1	TICCR	—	—	—	—	I2BE	I2AE	I1BE	I1AE
MTU2	TCR	—	CCLR[1:0]		CKEG[1:0]		TPSC[2:0]		
MTU2	TMDR1	—	—	—	—	MD[3:0]			
MTU2	TIOR	IOB[3:0]				IOA[3:0]			
MTU2	TIER	TTGE	—	TCIEU	TCIEV	—	—	TGIEB	TGIEA
MTU2	TSR	TCFD	—	TCFU	TCFV	—	—	TGFB	TGFA
MTU2	TCNT								
MTU2	TGRA								
MTU2	TGRB								
MTU6	TCR	CCLR[20]			CKEG[1:0]		TPSC[2:0]		
MTU7	TCR	CCLR[20]			CKEG[1:0]		TPSC[2:0]		
MTU6	TMDR1	—	—	BFB	BFA	MD[3:0]			
MTU7	TMDR1	—	—	BFB	BFA	MD[3:0]			
MTU6	TIORH	IOB[3:0]				IOA[3:0]			
MTU6	TIORL	IOD[3:0]				IOC[3:0]			
MTU7	TIORH	IOB[3:0]				IOA[3:0]			

Table 5.2 List of I/O Registers (Bit Order) (24 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
MTU7	TIORL	IOD[3:0]				IOC[3:0]			
MTU6	TIER	TTEG	—	—	TCIEV	TGIED	TGIEC	TGIEB	TGIEA
MTU7	TIER	TTEG	TTEG2	—	TCIEV	TGIED	TGIEC	TGIEB	TGIEA
MTU	TOERB	—	—	OE7D	OE7C	OE6D	OE7B	OE7A	OE6B
MTU	TOCR1B	—	PSYE	—	—	TOCL	TOCS	OLSN	OLSP
MTU6	TCNT								
MTU7	TCNT								
MTU	TCDRB								
MTU	TDDRB								
MTU6	TGRA								
MTU6	TGRB								
MTU7	TGRA								
MTU7	TGRB								
MTU	TCNTSB								
MTU	TCBRB								
MTU6	TGRC								
MTU6	TGRD								
MTU7	TGRC								
MTU7	TGRD								
MTU6	TSR	TCFD	—	—	TCFV	TGFD	TGFC	TGFB	TGFA
MTU7	TSR	TCFD	—	—	TCFV	TGFD	TGFC	TGFB	TGFA
MTU	TITCR1B	T6AEN	T6ACOR[2:0]			T7VEN	T7VCOR[2:0]		
MTU	TITCNT1B	—	T6ACNT[2:0]			—	T7VCNT[2:0]		
MTU	TBTERB	—	—	—	—	—	—	BTE[1:0]	
MTU	TDERB	—	—	—	—	—	—	—	TDER
MTU	TOLBRB	—	—	OLS3N	OLS3P	OLS2N	OLS2P	OLS1N	OLS1P
MTU6	TBTM	—	—	—	—	—	—	TTSB	TTSA
MTU7	TBTM	—	—	—	—	—	—	TTSB	TTSA
MTU	TITMRB	—	—	—	—	—	—	—	TITM
MTU	TITCR2B	—	—	—	—	—	TRGCOR[2:0]		
MTU	TITCNT2B	—	—	—	—	—	TRG7CNT[2:0]		
MTU7	TADCR	BF[1:0]		—	—	—	—	—	—
		UT7AE	DT7AE	UT7BE	DT7BE	ITA6AE	ITA7VE	ITB6AE	ITB7VE

Table 5.2 List of I/O Registers (Bit Order) (25 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
MTU7	TADCORA								
MTU7	TADCORB								
MTU7	TADCOBRA								
MTU7	TADCOBRB								
MTU	TSYCR	CE0A	CE0D	CE0C	CE0D	CE1A	CE1B	CE2A	CE2B
MTU	TWCRB	CCE	—	—	—	—	—	SCC	WRE
MTU	TMDR2B	—	—	—	—	—	—	—	DRS
MTU6	TGRE								
MTU7	TGRE								
MTU7	TGRF								
MTU	TSTRB	CST7	CST6	—	—	—	—	—	—
MTU	TSYRB	SYNC7	SYNC6	—	—	—	—	—	—
MTU	TRWERB	—	—	—	—	—	—	—	RWE
MTU5	TCNTU								
MTU5	TGRU								
MTU5	TCRU	—	—	—	—	—	—	TPSC[1:0]	
MTU5	TIORU	—	—	—	IOC[4:0]				
MTU5	TCNTV								
MTU5	TGRV								
MTU5	TCRV	—	—	—	—	—	—	TPSC[1:0]	
MTU5	TIORV	—	—	—	IOC[4:0]				
MTU5	TCNTW								
MTU5	TGRW								
MTU5	TCRW	—	—	—	—	—	—	TPSC[1:0]	
MTU5	TIORW	—	—	—	IOC[4:0]				
MTU5	TSR	—	—	—	—	—	CMFU5	CMFV5	CMFW5
MTU5	TIER	—	—	—	—	—	TGIE5U	TGIE5V	TGIE5W
MTU5	TSTR	—	—	—	—	—	CSTU5	CSTV5	CSTW5
MTU5	TCNTCMPCLR	—	—	—	—	—	CMPCLR5U	CMPCLR5V	CMPCLR5W
GPT	GTSTR	—	—	—	—	—	—	—	—
		—	—	—	—	CST3	CST2	CST1	CST0
GPT	GTHSCR	CPHW3[1:0]		CPHW2[1:0]		CPHW1[1:0]		CPHW0[1:0]	
		CSHW3[1:0]		CSHW2[1:0]		CSHW1[1:0]		CSHW0[1:0]	
GPT	GTHCCR	—	—	—	—	CCSW3	CCSW2	CCSW1	CCSW0
		CCHW3[1:0]		CCHW2[1:0]		CCHW1[1:0]		CCHW0[1:0]	

Table 5.2 List of I/O Registers (Bit Order) (26 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
GPT	GTHSSR	CSHSL3[3:0]				CSHSL2[3:0]			
		CSHSL1[3:0]				CSHSL0[3:0]			
GPT	GTHPSR	CSHPL3[3:0]				CSHPL2[3:0]			
		CSHPL1[3:0]				CSHPL0[3:0]			
GPT	GTWP	—	—	—	—	—	—	—	—
		—	—	—	—	WP3	WP2	WP1	WP0
GPT	GTSYNC	—	—	SYNC3[1:0]		—	—	SYNC2[1:0]	
		—	—	SYNC1[1:0]		—	—	SYNC0[1:0]	
GPT	GTETINT	—	—	—	—	—	—	ETINF	ETIPF
		—	—	—	—	—	—	ETINEN	ETIPEN
GPT	GTBDR	BD33	BD32	BD31	BD30	BD23	BD22	BD21	BD20
		BD13	BD12	BD11	BD10	BD03	BD02	BD01	BD00
GPT	GTSWP	—	—	—	—	—	—	—	—
		—	—	—	—	SWP3	SWP2	SWP1	SWP0
GPT	LCCR	LPSC[1:0]		TPSC[1:0]		LCNTAT	LCTO[2:0]		
		—	LCINTO	LCINTD	LCINTC	—	LCNTS	LCNTCR	LCNTE
GPT	LCST	—	—	—	—	—	—	—	—
		—	—	—	—	—	LISO	LISD	LISC
GPT	LCNTA								
GPT	LCNT00								
GPT	LCNT01								
GPT	LCNT02								
GPT	LCNT03								
GPT	LCNT04								
GPT	LCNT05								
GPT	LCNT06								
GPT	LCNT07								
GPT	LCNT08								
GPT	LCNT09								
GPT	LCNT10								
GPT	LCNT11								

Table 5.2 List of I/O Registers (Bit Order) (27 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
GPT	LCNT12								
GPT	LCNT13								
GPT	LCNT14								
GPT	LCNT15								
GPT	LCNTDU								
GPT	LCNTDL								
GPT0	GTIOR	OBHLD	OBDFLT	GTIOB[5:0]					
		OAHLD	OADFLT	GTIOA[5:0]					
GPT0	GTINTAD	ADTRBDEN	ADTRBUEN	ADTRADEN	ADTRAUEN	EINT	—	—	—
		GTINTPR[1:0]		GTINTF	GTINTE	GTINTD	GTINTC	GTINTB	GTINTA
GPT0	GTCR	—	—	CCLR[1:0]		—	—	TPCS[1:0]	
		—	—	—	—	—	MD[2:0]		
GPT0	GTBER	—	ADTDB	ADTTB[1:0]		—	ADTDA	ADTTA[1:0]	
		—	CCRSWT	PR[1:0]		CCRB[1:0]		CCRA[1:0]	
GPT0	GTUDC	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	UDF	UD
GPT0	GTITC	—	ADTBL	—	ADTAL	—	IVTT[2:0]		
		IVTC[1:0]		ITLF	ITLE	ITLD	ITLC	ITLB	ITLA
GPT0	GTST	TUCF	—	—	—	DTEF	ITCNT[2:0]		
		TCFPU	TCFPO	TCFF	TCFE	TCFD	TCFC	TCFB	TCFA
GPT0	GTCNT								
GPT0	GTCCRA								
GPT0	GTCCRB								
GPT0	GTCCRC								
GPT0	GTCCRD								
GPT0	GTCCRE								
GPT0	GTCCRF								
GPT0	GTPR								
GPT0	GTPBR								

Table 5.2 List of I/O Registers (Bit Order) (28 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
GPT0	GTPDBR								
GPT0	GTADTRA								
GPT0	GTADTBRA								
GPT0	GTADTDBRA								
GPT0	GTADTRB								
GPT0	GTADTBRB								
GPT0	GTADTDBRB								
GPT0	GTONCR	OBE	OAE	—	SWN	—	—	—	NFV
		NFS[3:0]				NVB	NVA	NEB	NEA
GPT0	GTDTCR	—	—	—	—	—	—	—	TDFER
		—	—	TDBDE	TDBUE	—	—	—	TDE
GPT0	GTDVU								
GPT0	GTDVD								
GPT0	GTDBU								
GPT0	GTDBD								
GPT0	GTSOS	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	SOS[1:0]	
GPT0	GTSOTR	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	SOTR
GPT1	GTIOR	OBHLD	OBDFLT	GTIOB[5:0]					
		OAHLD	OADFLT	GTIOA[5:0]					
GPT1	GTINTAD	ADTRBDEN	ADTRBUEN	ADTRADEN	ADTRAUEN	EINT	—	—	—
		GTINTPR[1:0]		GTINTF	GTINTE	GTINTD	GTINTC	GTINTB	GTINTA
GPT1	GTCR	—	—	CCLR[1:0]		—	—	TPCS[1:0]	
		—	—	—	—	—	MD[2:0]		
GPT1	GTBER	—	ADTDB	ADTTB[1:0]		—	ADTDA	ADTTA[1:0]	
		—	CCRSWT	PR[1:0]		CCRB[1:0]		CCRA[1:0]	
GPT1	GTUDC	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	UDF	UD
GPT1	GTITC	—	ADTBL	—	ADTAL	—	IVTT[2:0]		
		IVTC[1:0]		ITLF	ITLE	ITLD	ITLC	ITLB	ITLA
GPT1	GTST	TUCF	—	—	—	DTEF	ITCNT[2:0]		
		TCFPU	TCFPO	TCFF	TCFE	TCFD	TCFC	TCFB	TCFA

Table 5.2 List of I/O Registers (Bit Order) (29 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
GPT1	GTCNT								
GPT1	GTCCRA								
GPT1	GTCCRB								
GPT1	GTCCRC								
GPT1	GTCCRD								
GPT1	GTCCRE								
GPT1	GTCCRF								
GPT1	GTPR								
GPT1	GTPBR								
GPT1	GTPDBR								
GPT1	GTADTRA								
GPT1	GTADTBRA								
GPT1	GTADTDBRA								
GPT1	GTADTRB								
GPT1	GTADTBRB								
GPT1	GTADTDBRB								
GPT1	GTONCR	OBE	OAE	—	SWN	—	—	—	NFV
		NFS[3:0]				NVB	NVA	NEB	NEA
GPT1	GTDTCR	—	—	—	—	—	—	—	TDFER
		—	—	TDBDE	TDBUE	—	—	—	TDE
GPT1	GTDVU								
GPT1	GTDVD								
GPT1	GTDBU								
GPT1	GTDBD								

Table 5.2 List of I/O Registers (Bit Order) (30 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
GPT1	GTSOS	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	SOS[1:0]	
GPT1	GTSOTR	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	SOTR
GPT2	GTIOR	OBHLD	OBDFLT	GTIOB[5:0]					
		OAHLD	OADFLT	GTIOA[5:0]					
GPT2	GTINTAD	ADTRBDEN	ADTRBUEN	ADTRADEN	ADTRAUEN	EINT	—	—	—
		GTINTPR[1:0]		GTINTF	GTINTE	GTINTD	GTINTC	GTINTB	GTINTA
GPT2	GTCR	—	—	CCLR[1:0]		—	—	TPCS[1:0]	
		—	—	—	—	—	MD[2:0]		
GPT2	GTBER	—	ADTDB	ADTTB[1:0]		—	ADTDA	ADTTA[1:0]	
		—	CCRSWT	PR[1:0]		CCRB[1:0]		CCRA[1:0]	
GPT2	GTUDC	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	UDF	UD
GPT2	GTITC	—	ADTBL	—	ADTAL	—	IVTT[2:0]		
		IVTC[1:0]		ITLF	ITLE	ITLD	ITLC	ITLB	ITLA
GPT2	GTST	TUCF	—	—	—	DTEF	ITCNT[2:0]		
		TCFPU	TCFPO	TCFF	TCFE	TCFD	TCFC	TCFB	TCFA
GPT2	GTCNT								
GPT2	GTCCRA								
GPT2	GTCCRB								
GPT2	GTCCRC								
GPT2	GTCCRD								
GPT2	GTCCRE								
GPT2	GTCCRF								
GPT2	GTPR								
GPT2	GTPBR								
GPT2	GTPDBR								
GPT2	GTADTRA								
GPT2	GTADTBRA								
GPT2	GTADTDBRA								

Table 5.2 List of I/O Registers (Bit Order) (31 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
GPT2	GTADTRB								
GPT2	GTADTBRB								
GPT2	GTADTDBRB								
GPT2	GTONCR	OBE	OAE	—	SWN	—	—	—	NFV
		NFS[3:0]				NVB	NVA	NEB	NEA
GPT2	GTDTCR	—	—	—	—	—	—	—	TDFER
		—	—	TDBDE	TDBUE	—	—	—	TDE
GPT2	GTDVU								
GPT2	GTDVD								
GPT2	GTDBU								
GPT2	GTDBD								
GPT2	GTSOS	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	SOS[1:0]	
GPT2	GTSOTR	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	SOTR
GPT3	GTIOR	OBHLD	OBDFLT	GTIOB[5:0]					
		OAHLD	OADFLT	GTIOA[5:0]					
GPT3	GTINTAD	ADTRBDEN	ADTRBUEN	ADTRADEN	ADTRAUEN	EINT	—	—	—
		GTINTPR[1:0]		GTINTF	GTINTE	GTINTD	GTINTC	GTINTB	GTINTA
GPT3	GTCR	—	—	CCLR[1:0]		—	—	—	—
		—	—	—	—	—	—	—	—
GPT3	GTBER	—	ADTDB	ADTTB[1:0]		—	ADTDA	ADTTA[1:0]	
		—	CCRSWT	PR[1:0]		CCRB[1:0]		CCRA[1:0]	
GPT3	GTUDC	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	UDF	UD
GPT3	GTITC	—	ADTBL	—	ADTAL	—	IVTT[2:0]		
		IVTC[1:0]		ITLF	ITLE	ITLD	ITLC	ITLB	ITLA
GPT3	GTST	TUCF	—	—	—	DTEF	ITCNT[2:0]		
		TCFPU	TCFPO	TCFF	TCFE	TCFD	TCFC	TCFB	TCFA
GPT3	GTCNT								
GPT3	GTCCRA								
GPT3	GTCCRB								
GPT3	GTCCRC								

Table 5.2 List of I/O Registers (Bit Order) (32 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
GPT3	GTCCRD								
GPT3	GTCCRE								
GPT3	GTCCRF								
GPT3	GTPR								
GPT3	GTPBR								
GPT3	GTPDBR								
GPT3	GTADTRA								
GPT3	GTADTBRA								
GPT3	GTADTDBRA								
GPT3	GTADTRB								
GPT3	GTADTBRB								
GPT3	GTADTDBRB								
GPT3	GTONCR	OBE	OAE	—	SWN	—	—	—	NFV
		NFS[3:0]				NVB	NVA	NEB	NEA
GPT3	GTDTCR	—	—	—	—	—	—	—	TDFER
		—	—	TDBDE	TDBUE	—	—	—	TDE
GPT3	GTDVU								
GPT3	GTDVD								
GPT3	GTDBU								
GPT3	GTDBD	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	SOS[1:0]	
GPT3	GTSOS	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	SOS[1:0]	
GPT3	GTSOTR	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	SOTR
FLASH	FMODR	—	—	—	FRDMD	—	—	—	—
FLASH	FASTAT	ROMAE	—	—	CMDLK	DFLAE	—	DFLRPE	DFLWPE
FLASH	FAEINT	ROMAEIE	—	—	CMDLKIE	DFLAEIE	—	DFLRPEIE	DFLWPEIE
FLASH	FRDYIE	—	—	—	—	—	—	—	FRDYIE

Table 5.2 List of I/O Registers (Bit Order) (33 / 33)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
FLASH	DFLRE0	KEY[7:0]							
		DBRE07	DBRE06	DBRE05	DBRE04	DBRE03	DBRE02	DBRE01	DBRE00
FLASH	DFLRE1	KEY[7:0]							
		DBRE15	DBRE14	DBRE13	DBRE12	DBRE11	DBRE10	DBRE09	DBRE08
FLASH	DFLWE0	KEY[7:0]							
		DBWE07	DBWE06	DBWE05	DBWE04	DBWE03	DBWE02	DBWE01	DBWE00
FLASH	DFLWE1	KEY[7:0]							
		DBWE15	DBWE14	DBWE13	DBWE12	DBWE11	DBWE10	DBWE09	DBWE08
FLASH	FCURAME	KEY[7:0]							
		—	—	—	—	—	—	—	FCRME
FLASH	FSTATR0	FRDY	ILGLERR	ERSERR	PRGERR	SUSRDY	—	ERSSPD	PRGSPD
FLASH	FSTATR1	FCUERR	—	—	FLOCKST	—	—	—	—
FLASH	FENTRYR	FEKEY[7:0]							
		FENTRYD	—	—	—	—	—	—	FENTRY0
FLASH	FPROTR	FPKEY[7:0]							
		—	—	—	—	—	—	—	FPROTCN
FLASH	FRESETR	FRKEY[7:0]							
		—	—	—	—	—	—	—	FRESET
FLASH	FCMDR	CMDR[7:0]							
		PCMDR[7:0]							
FLASH	FCPSR	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	ESUSPMD
FLASH	DFLBCCNT	—	—	—	—	—	BCADR[7:0]		
		BCADR[7:0]						—	BCSIZE
FLASH	FPESTAT	—	—	—	—	—	—	—	—
		PEERRST[7:0]							
FLASH	DFLBCSTAT	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	BCST
FLASH	PCKAR	—	—	—	—	—	—	—	—
		PCKA[7:0]							

Note: • In this, the I/O port related registers (0008 C001h to 0008 C116h) indicate the bit configuration of the 112-pin LQFP version. As the configuration of registers and bits differs depending on a package, see section 15, I/O Ports, for details.

Note 1. This shows the bit configuration when ADDPR.DPSEL = 0 and ADDPR.DPPRC = 0 (The value has 10-bit accuracy and is padded at the LSB end).

Note 2. This shows the bit configuration when ADCER.ADRFMT = 0 (aligned to the LSB end) and ADCER.ADPRC[1:0] = 00b. For details, refer to section 28, 12-Bit A/D Converter (S12ADA).

Note 3. This function is not supported by the product without the CAN function.

6. Resets

6.1 Overview

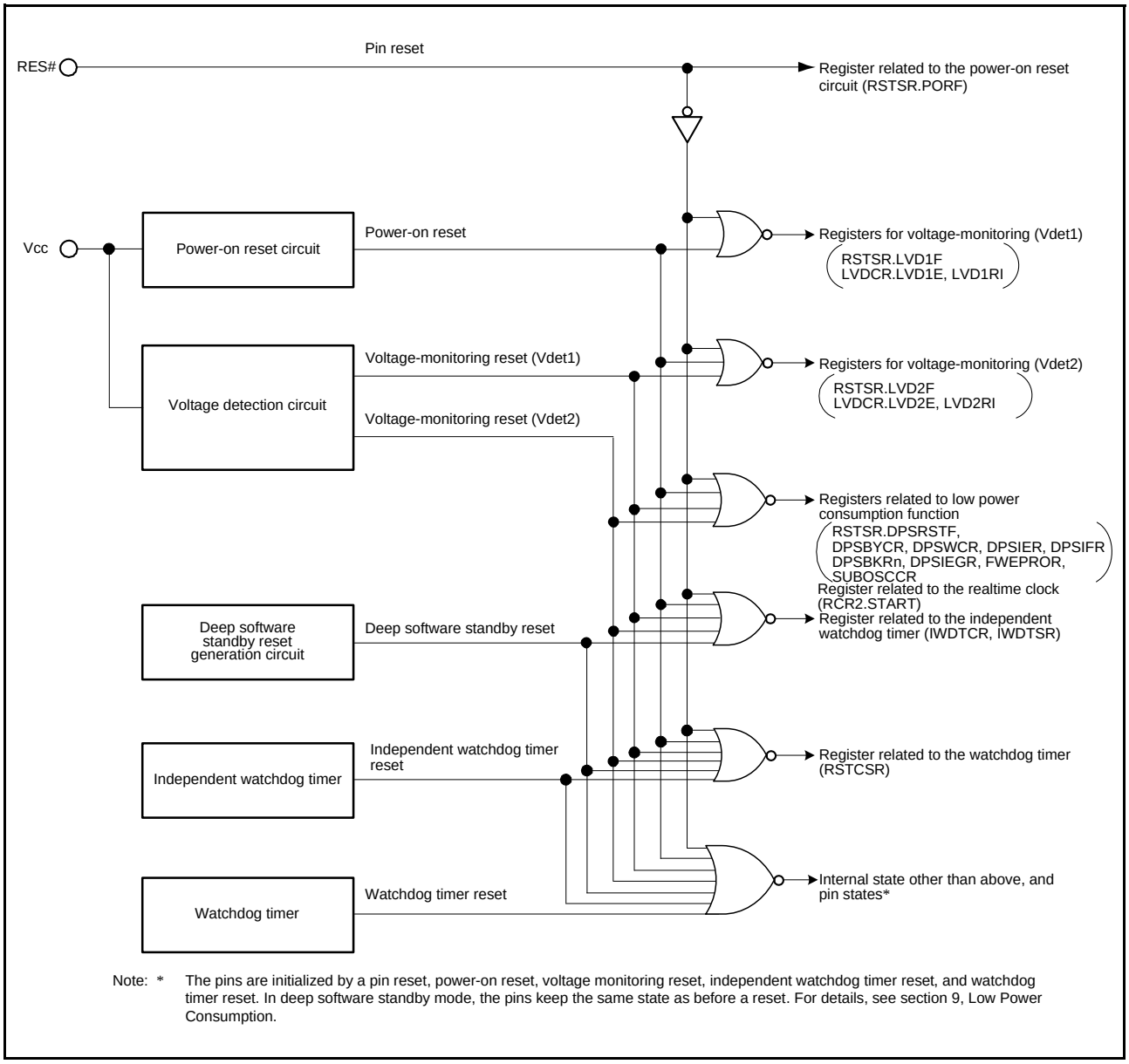
There are six types of resets: a pin reset, power-on reset, voltage-monitoring reset, deep software standby reset, independent watchdog timer reset, and watchdog timer reset.Table 6.1 shows the reset names and sources.

Table 6.1 Reset Names and Sources

Reset Name	Source
Pin reset	Voltage input to the RES# pin is driven low.
Power-on reset	Vcc rises or falls (voltage detection: V_{POR})
Voltage-monitoring reset	Vcc falls (voltage detection: Vdet1 and Vdet2)*
Deep software standby reset	Deep software standby mode is canceled by an interrupt.
Independent watchdog timer reset	The independent watchdog timer underflows.
Watchdog timer reset	The watchdog timer overflows.

Note: • For the voltages to be monitored (Vdet1, Vdet2, and V_{POR}), see section 7, Voltage Detection Circuit (LVD) and section 33, Electrical Characteristics

The internal state and pins are initialized by a reset. Figure 6.1 shows the reset targets to be initialized.



Note: * The pins are initialized by a pin reset, power-on reset, voltage monitoring reset, independent watchdog timer reset, and watchdog timer reset. In deep software standby mode, the pins keep the same state as before a reset. For details, see section 9, Low Power Consumption.

Figure 6.1 Block Diagram of Reset Circuit

Table 6.2 Targets to be Initialized by Each Reset Type

Targets to be Initialized	Pin Reset	Power-On Reset	Voltage-Monitoring Reset		Deep Software Standby Reset	Independent Watchdog Timer Reset	Watchdog Timer Reset
			Vdet1	Vdet2			
Register related to the power-on reset circuit RSTSR.PORF	√	—	—	—	—	—	—
Registers related to the voltage monitor function (Vdet1) RSTSR. LVD1F, LVDCR. LVD1E, LVD1RI	√	√	—	—	—	—	—
Registers related to the voltage monitor function (Vdet2) RSTSR.LVD2F, LVDCR.LVD2E, LVD2RI	√	√	√	—	—	—	—
Registers related to the low power-consumption function RSTSR.DPSRSTF, DPSBYCR, DPSWCR, DPSIER, DPSIFR, DPSBKRn, DPSIEGR, FWEPROR, SUBOSCCR	√	√	√	√	—	—	—
Register related to the independent watchdog timer IWDTCR, IWDTSR	√	√	√	√	√	—	—
Register related to the watchdog timer RSTCSR	√√	√	√	√	√	√	—
Registers other than the above and internal state	√	√	√	√	√	√	√
Pin state	√	√	√	√	—	√	√

When a reset is canceled, the reset exception handling is started. For the reset exception handling, see section 10, Exceptions.

Table 6.3 shows the pin related to the resets.

Table 6.3 Pin Related to Reset

Pin Name	I/O	Function
RES#	Input	Reset input

6.2 Register Descriptions

Table 6.4 shows the registers related to the resets.
Each register has the bits to indicate the source of each reset generated.

Table 6.4 Registers Related to Resets

Register Name	Symbol	Value after Reset*1	Address	Access Size
Reset status register	RSTSR	x000 0xxxb	0008 C285h	8
Reset control/status register	RSTCSR	1Fh	0008 802Bh	8
IWDT status register	IWDTSR	0000h	0008 8034h	16

Note 1. The applicable reset type depends on the register; see Figure 6.1, Block Diagram of Reset Circuit and Figure 6.2, Power-On Reset Operation.

6.2.1 Reset Status Register (RSTSR)

For details on the RSTSR register, see section 9, Low Power Consumption.

6.2.2 Reset Control/Status Register (RSTCSR)

For details on the RSTCSR register, see section 20, Watchdog Timer (WDT).

6.2.3 IWDT Status Register (IWDTSR)

For details on the IWDTSR register, see section 21, Independent Watchdog Timer (IWDT).

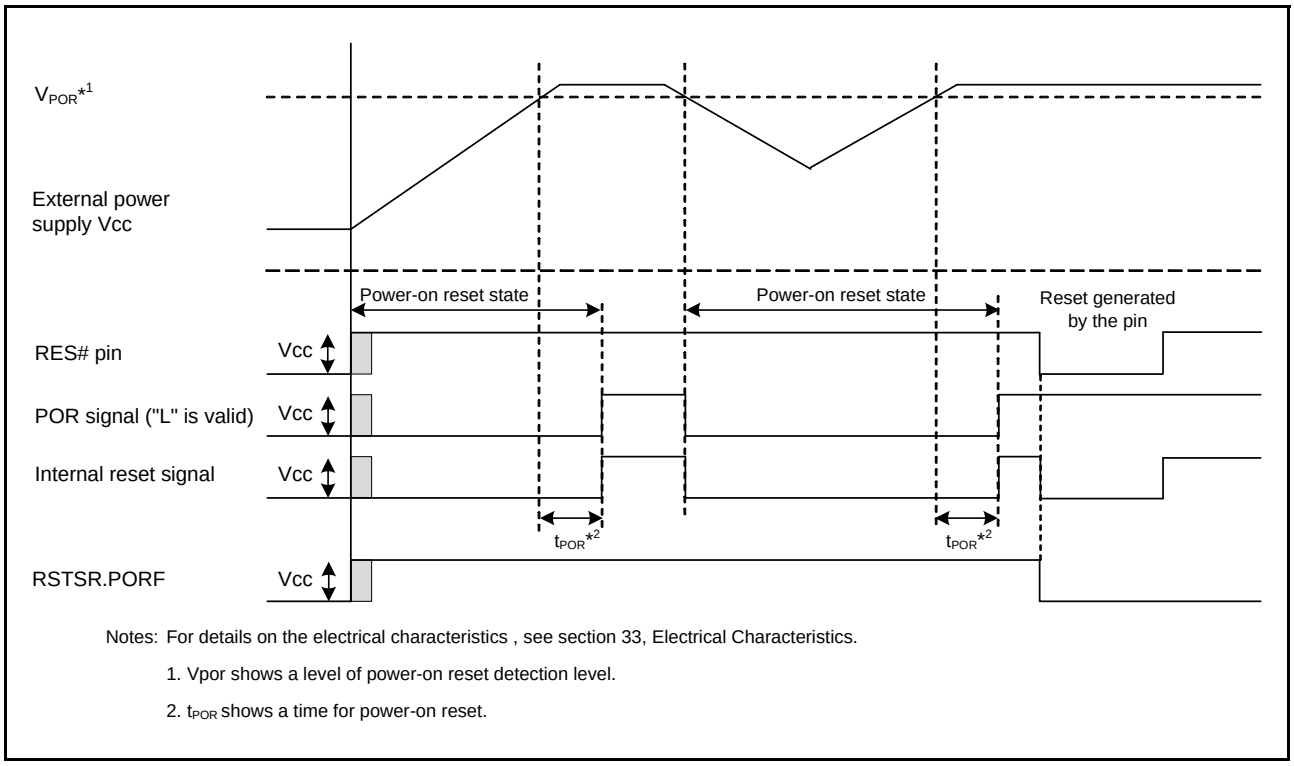
6.3 Operation

6.3.1 Pin Reset

This is a reset generated by the RES# pin.
When the RES# pin is driven low, all the processing in progress is aborted and the RX62T enters a reset state.
In order to firmly reset the LSI, the RES# pin should be held low for the specified oscillation stabilization time at a power-on. During operation, the RES# pin should be held low according to the specified reset pulse width.
For details, refer to section 33, Electrical Characteristics.

6.3.2 Power-On Reset

This is an internal reset generated by the power-on reset circuit.
If the RES# pin is in the high level state when power is supplied, a power-on reset is generated. After Vcc has exceeded Vpor and the specified period (power-on reset time) has elapsed, the chip is released from the power-on reset state. The power-on reset time is a period for stabilization of the external power supply and the LSI circuit.
If the RES# pin is at the high level when the power supply voltage (Vcc) falls to or below Vpor, a power-on reset is generated. The chip is released from the power-on reset state after Vcc has risen above Vpor and the power-on reset time has elapsed.
After a power-on reset has been generated, the PORF flag in RSTSR is set to 1. The PORF flag in RSTSR is in a read-only register and is only initialized by a pin reset.
Figure 6.2shows the operation of a power-on reset.



Notes: For details on the electrical characteristics , see section 33, Electrical Characteristics.

1. Vpor shows a level of power-on reset detection level.
2. t_{POR} shows a time for power-on reset.

Figure 6.2 Power-On Reset Operation

6.3.3 Voltage-Monitoring Reset

This is an internal reset generated by the voltage detection circuit.
The LVD1F flag in RSTSR is set to 1 when Vcc falls below Vdet1. If the value of the LVD1E bit is 1 (triggering of reset or interrupt by the voltage detection circuit is enabled) and that of the LVD1RI bit is 0 (a reset is generated by low voltage detection) in LVDCR at this time, a voltage-monitoring reset is generated by the voltage detection circuit.
In a similar way, the LVD2F flag in RSTSR is set to 1 when Vcc falls below Vdet2. If the value of the LVD2E bit is 1 (triggering of a reset or interrupt by the voltage detection circuit is enabled) and that of the LVD2RI bit is 0 (a reset is generated by low voltage detection) in LVDCR at this time, a voltage-monitoring reset is generated by the voltage detection circuit.
When Vcc subsequently rises above Vdet1 or Vdet2, release from the voltage-monitoring reset proceeds after a specified stabilization time has elapsed.
For details of the voltage-monitoring reset, see section 7, Voltage Detection Circuit (LVD), and section 33, Electrical Characteristics.

6.3.4 Deep Software Standby Reset

This is an internal reset generated when deep software standby mode is canceled by an interrupt.
When deep software standby mode is canceled, a deep software standby reset is generated, and simultaneously, clock oscillation starts. After the time specified with the deep software standby wait time setting bits (DPSWCR.WTSTS[5:0]) has elapsed, the deep software standby reset is canceled.
For details of the deep software standby reset, see section 9, Low Power Consumption.

6.3.5 Independent Watchdog Timer Reset

This is an internal reset generated by the independent watchdog timer.
When the independent watchdog timer underflows, an independent watchdog timer reset is generated. A reset is also generated if write operation is performed while refresh operation is not enabled. After a certain time, the independent watchdog timer reset is canceled.
For details of the independent watchdog timer reset, see section 21, Independent Watchdog Timer (IWDT).

6.3.6 Watchdog Timer Reset

This is an internal reset generated by the watchdog timer.
When the RSTE bit in RSTCSR is set to 1, a watchdog timer reset is generated by a watchdog timer overflow. After a certain time, the watchdog timer reset is canceled.
For details of the watchdog timer reset, see section 20, Watchdog Timer (WDT).

6.4 Determination of Reset Generation Source

Reading RSTCSR, IWDTSR, RSTSR, and LVDCR determines which reset was used to execute the reset exception handling.

Figure 6.3 shows an example of the flow to identify a reset generation source.

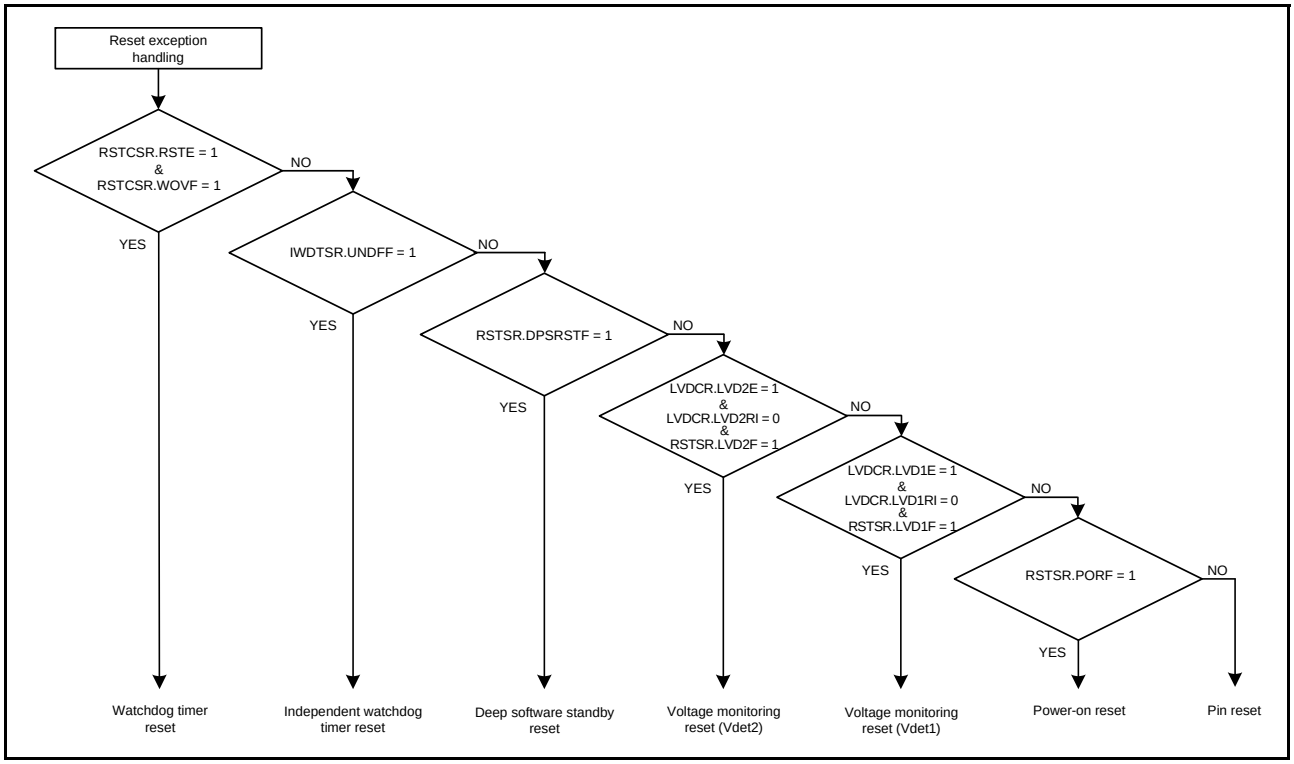


Figure 6.3 Example of Reset Generation Source Determination Flow

6.5 Usage Notes

6.5.1 Notes on Board Design

The XTAL pin and the reset pin are crossly arranged on the RX62T Group. Therefore, to avoid the reference from the clock signal, the reset signal should be guarded by GND.

7. Voltage Detection Circuit (LVD)

7.1 Overview

The voltage detection circuit (LVD) is used to monitor the Vcc voltage level. The LVD is capable of internally resetting the LSI when Vcc falls to the voltage detection level. An interrupt can also be generated.

Specifications of Voltage Detection Circuit

Table 7.1 Specifications of Voltage Detection Circuit

Item	Specification
Voltage detection circuit 1 (LVD1)	• Capable of detecting the power-supply voltage (Vcc) becoming less than or equal to Vdet1*. • Capable of generating an internal reset or interrupt when a low voltage is detected.
Voltage detection circuit 2 (LVD2)	• Capable of detecting the power-supply voltage (Vcc) becoming less than or equal to Vdet2*. • Capable of generating an internal reset or interrupt when a low voltage is detected.

Note: • For Vdet1 and Vdet2, see section 33, Electrical Characteristics.

Figure 7.1 shows a block diagram of the voltage detection circuit.

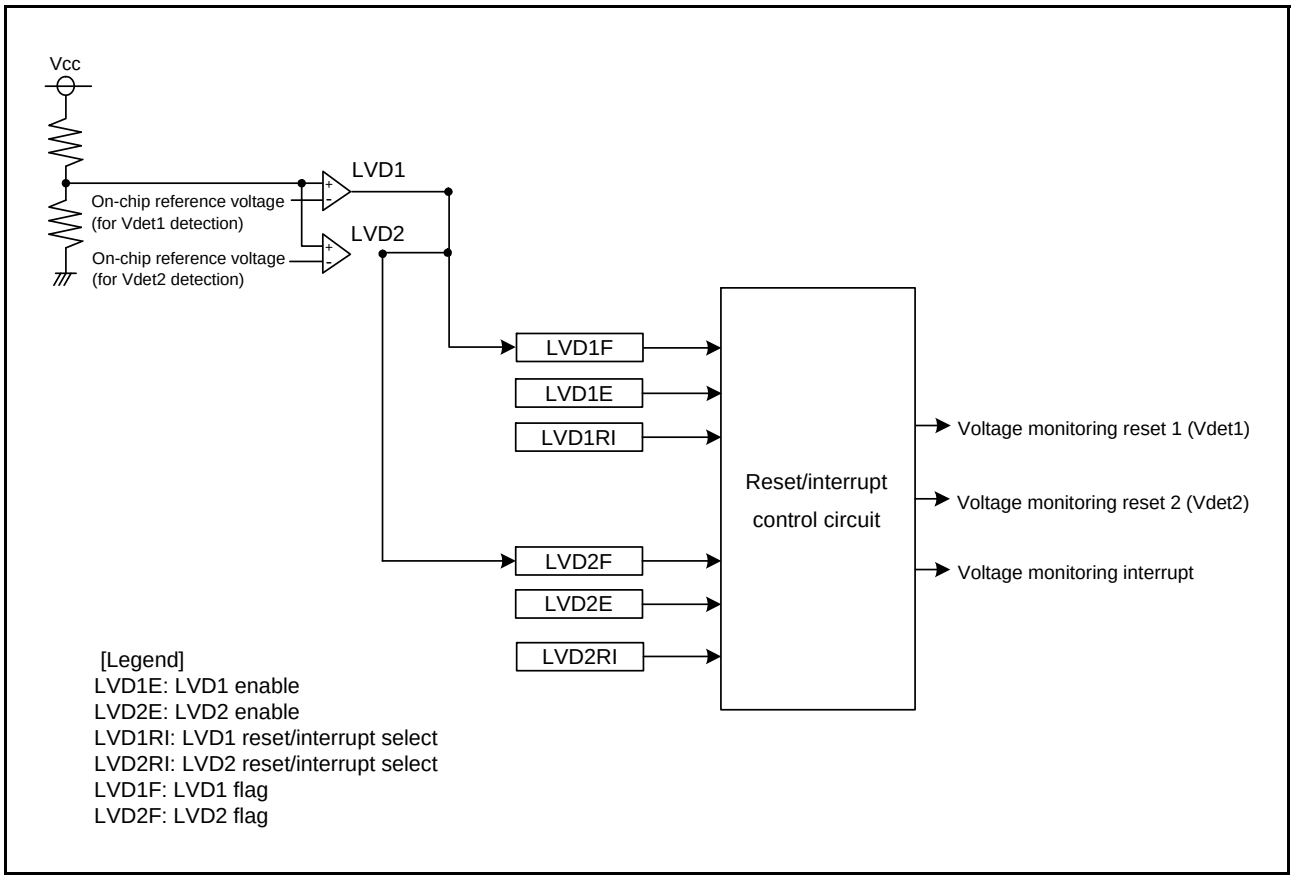


Figure 7.1 Block Diagram of Voltage Detection Circuit

7.2 Register Descriptions

Table 7.2is the list of voltage detection circuit registers.

Table 7.2 List of Voltage Detection Circuit Registers

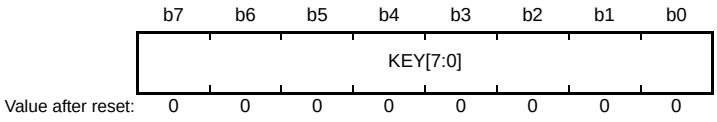
Register Name	Symbol	Value after Reset	Address	Access Size
Reset status register	RSTSR	x000 0xxxb	0008 C285h	8
Key code register for low-voltage detection control register	LVDKEYR	00h	0008 C28Ch	8
Low-voltage detection control register	LVDCR	000x 000xb	0008 C28Dh	8

7.2.1 Reset Status Register (RSTSR)

For details of RSTSR, see section 9, Low Power Consumption.

7.2.2 Key Code Register for Low-Voltage Detection Control Register (LVDKEYR)

Address: 0008 C28Ch



Bit	Symbol	Bit Name	Description	R/W
b7 to b0	KEY[7:0]	LVDCR Key Code	3Ch: Modifying LVDCR is enabled Others: Modifying LVDCR is disabled	R/W

LVDKEYR enables or disables writing to LVDCR.
After a specified key code is written to LVDKEYR, LVDCR can be written to.

KEY[7:0] Bits (LVDCR Key Code)

Writing 3Ch to LVDKEYR enables writing to LVDCR. While LVDKEYR holds a value other than 3Ch, writing to LVDCR is ignored. After LVDCR is written to, the KEY[7:0] bits are cleared to 00h.

7.2.3 Low-Voltage Detection Control Register (LVDCR)

Address: 0008 C28Dh

	b7	b6	b5	b4	b3	b2	b1	b0
	LVD2E	LVD2RI	—	—	LVD1E	LVD1RI	—	—
Value after reset:	0	0	0	x	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	—	Reserved	This bit is always read as undefined. Writing to this bit has no effect.	R/W
b1	—	Reserved	This bit is always read as 0. The write value should be 0.	R/W
b2	LVD1RI	LVD1 Reset/Interrupt Select	0: A reset is generated when a low voltage is detected 1: An interrupt is generated when a low voltage is detected	R/W
b3	LVD1E	LVD1 Enable	0: LVD1 is disabled 1: LVD1 is enabled	R/W
b4	—	Reserved	This bit is always read as undefined. Writing to this bit has no effect.	R/W
b5	—	Reserved	This bit is always read as 0. The write value should be 0.	R/W
b6	LVD2RI	LVD2 Reset/Interrupt Select	0: A reset is generated when a low voltage is detected 1: An interrupt is generated when a low voltage is detected	R/W
b7	LVD2E	LVD2 Enable	0: LVD2 is disabled 1: LVD2 is enabled	R/W

LVDCR controls the voltage detection circuit.
The LVD1E and LVD1RI bits are initialized by a pin reset or power-on reset.
The LVD2E and LVD2RI bits are initialized by a pin reset, power-on reset, or voltage monitoring reset 1 (Vdet1).
A key code must be written to LVDKEYR by KEY[7:0] bits before the LVDCR register is written to.
Table 7.3 shows the relationship between the LVDCR register settings and the states of the voltage detection circuits.

LVD1RI Bit (LVD1 Reset/Interrupt Select)

This bit selects whether an internal reset or interrupt is generated when voltage detection circuit 1 detects a low voltage.

LVD1E Bit (LVD1 Enable)

This bit enables or disables issuing of a reset or an interrupt by voltage detection circuit 1.

LVD2RI Bit (LVD2 Reset/Interrupt Select)

This bit selects whether an internal reset or interrupt is generated when voltage detection circuit 2 detects a low voltage.

LVD2E Bit (LVD2 Enable)

This bit enables or disables issuing of a reset or an interrupt by voltage detection circuit 2.

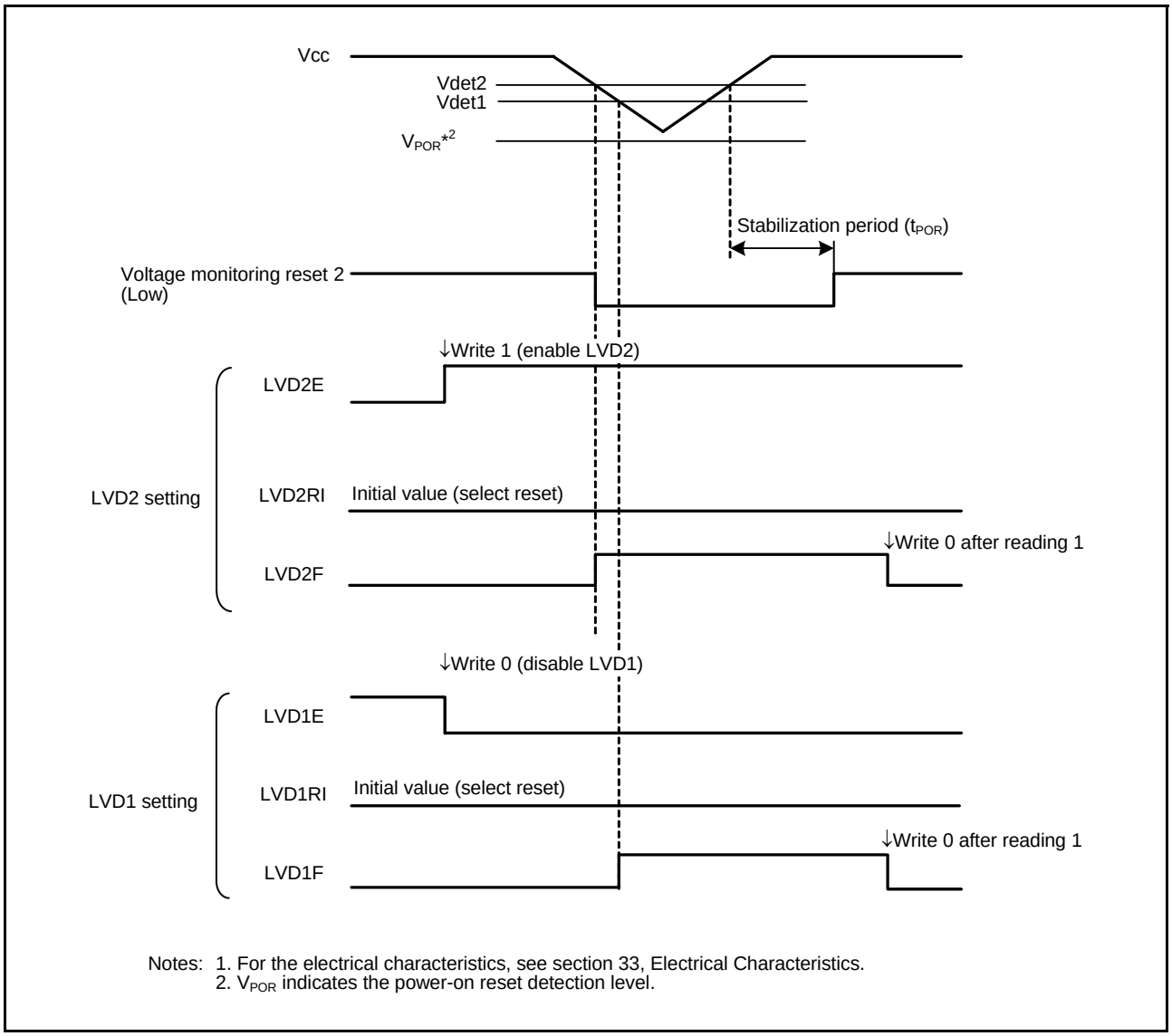
Table 7.3 LVDCR Register Settings and Voltage Detection Circuit States

LVDCR Register				Voltage Detection Circuit 2 (LVD2)	Voltage Detection Circuit 1 (LVD1)
LVD2E Bit	LVD2RI Bit	LVD1E Bit	LVD1RI Bit		
0	0	0	0	LVD2 disabled	LVD1 disabled
0	0	1	0	LVD2 disabled	LVD1 enabled (reset)
0	0	1	1	LVD2 disabled	LVD1 enabled (interrupt)
1	0	0	0	LVD2 enabled (reset)	LVD1 disabled
1	1	0	0	LVD2 enabled (interrupt)	LVD1 disabled
1	1	1	0	LVD2 enabled (interrupt)	LVD1 enabled (reset)
Other than above: Setting prohibited					

7.3 Voltage Detection Circuit

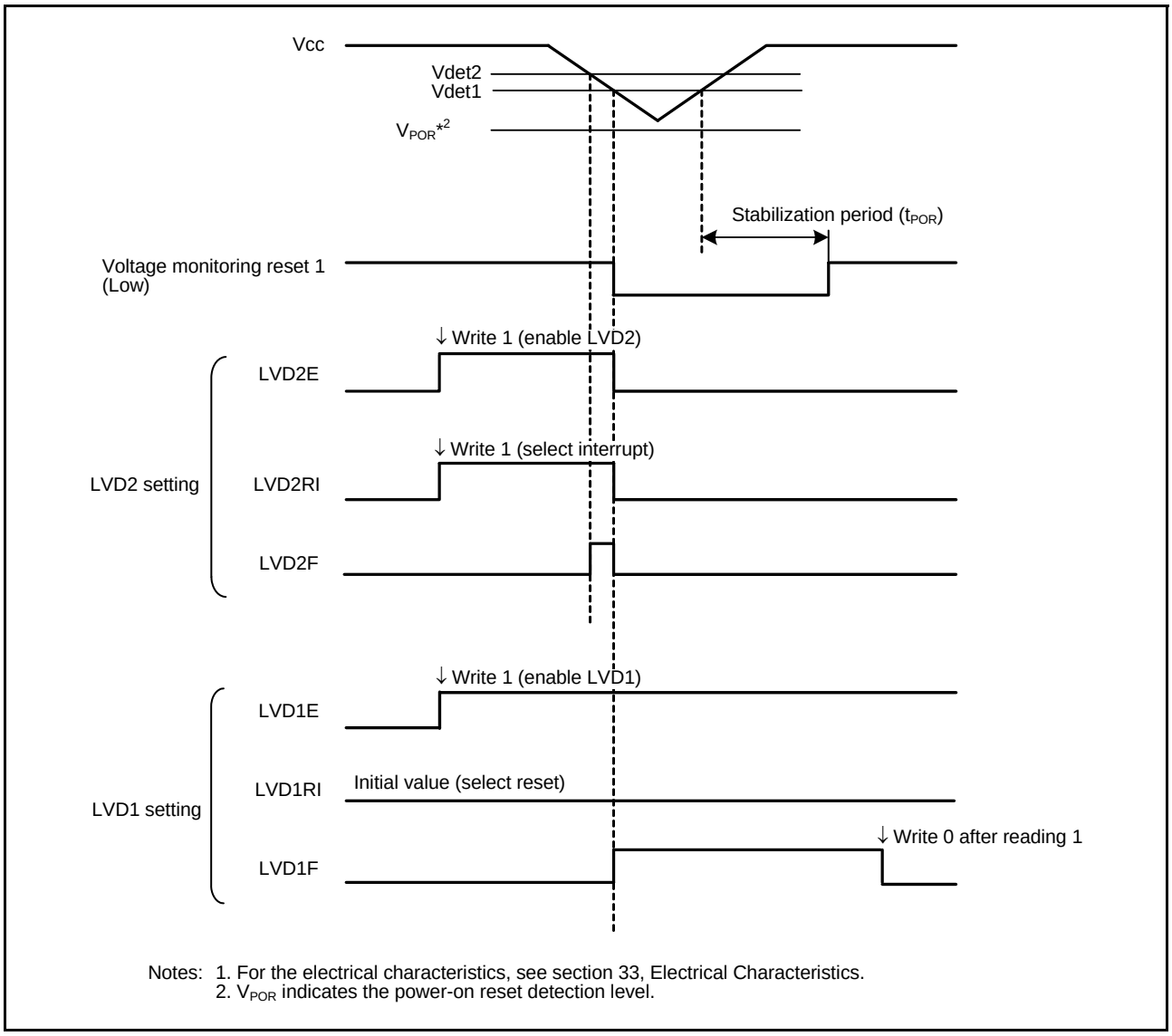
7.3.1 Voltage Monitoring Reset

Figure 7.2 andFigure 7.3 show the timing of a voltage monitoring reset by the voltage detection circuit.
The LVD2F flag in RSTSR is set to 1 when Vcc falls below Vdet2. If the value of the LVD2E bit is 1 and that of the LVD2RI bit is 0 in LVDCR at this time, a voltage-monitoring reset is generated by the voltage detection circuit.
In a similar way, the LVD1F flag in RSTSR is set to 1 when Vcc falls below Vdet1. If the value of the LVD1E bit is 1 and that of the LVD1RI bit is 0 in LVDCR at this time, a voltage-monitoring reset is generated by the voltage detection circuit.
Next, after Vcc has risen above Vdet1 or Vdet2, the voltage monitoring reset is canceled. After the voltage monitoring reset is canceled, the LSI starts reset exception handling.



Notes: 1. For the electrical characteristics, see section 33, Electrical Characteristics.
2. V_{POR} indicates the power-on reset detection level.

Figure 7.2 Timing Diagram 1 of Voltage Monitoring Reset (Reset Selected in LVD2, LVD1 Disabled)



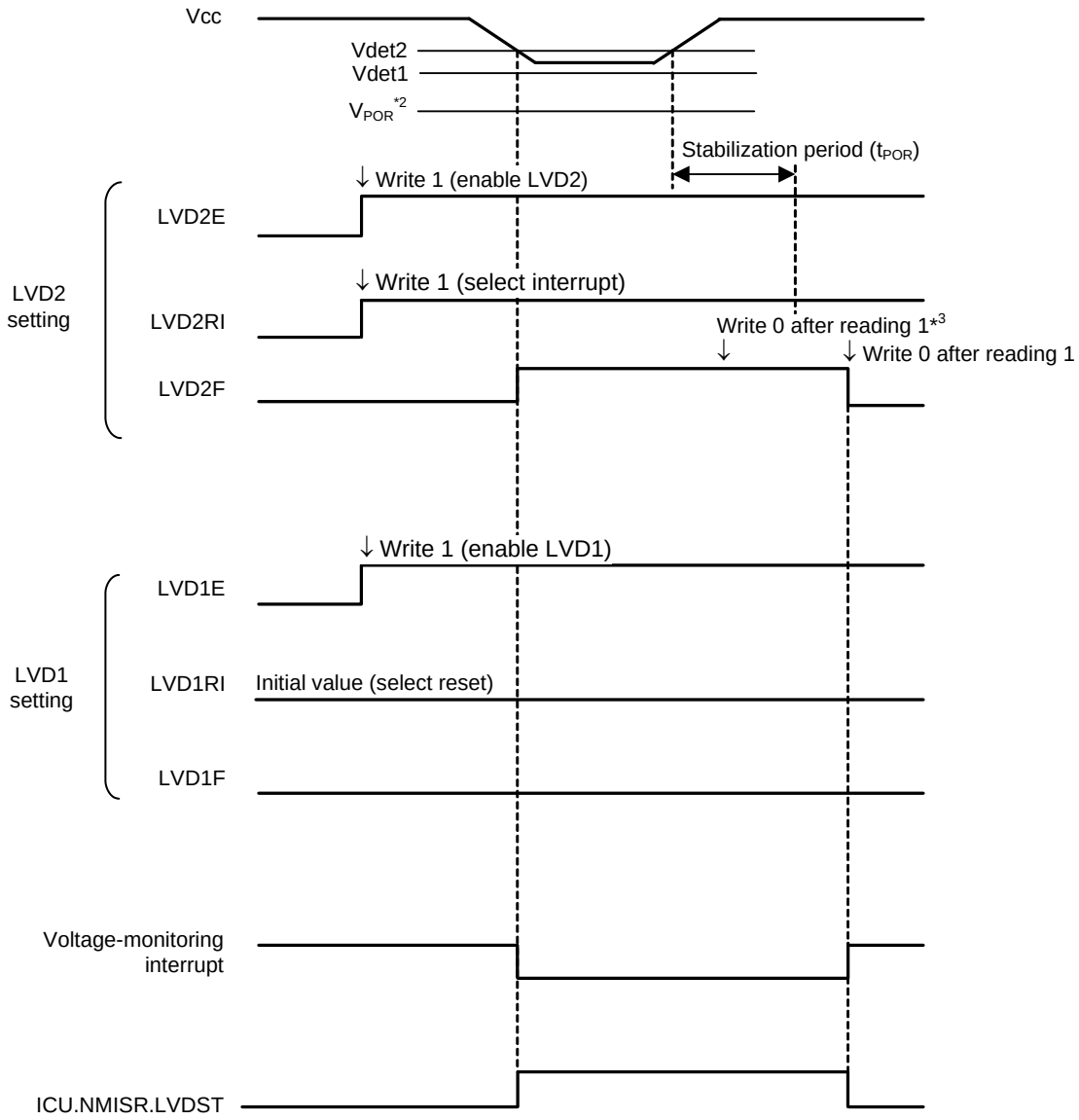
Notes: 1. For the electrical characteristics, see section 33, Electrical Characteristics.
2. V_{POR} indicates the power-on reset detection level.

Figure 7.3 Timing Diagram 2 of Voltage Monitoring Reset (Interrupt Selected in LVD2, Reset Selected in LVD1)

7.3.2 Voltage-Monitoring Interrupt

Figure 7.4 shows the timing of a voltage-monitoring interrupt by the voltage detection circuit.
The LVD1F flag in RSTSR is set to 1 when Vcc falls below Vdet1. If both the LVD1E and LVD1RI bits in LVDCR have the value 1 at this time, a voltage-monitoring interrupt is generated by the voltage detection circuit.
In a similar way, the LVD2F flag in RSTSR is set to 1 when Vcc falls below Vdet2. If both the LVD2E and LVD2RI bits in LVDCR have the value 1 at this time, a voltage-monitoring interrupt is generated by the voltage detection circuit.
The RSTSR.LVD1F flag can be cleared by writing 0 to the flag after reading it as 1. If the Vcc voltage level is equal to or lower than the LVD1 detection level (Vdet1) at this point, the RSTSR.LVD1F flag cannot be cleared. After 0 has been written to the RSTSR.LVD1F flag, reading 0 from the RSTSR.LVD1F flag will ensure that Vcc is higher than Vdet1.
Likewise, the RSTSR.LVD2F flag can be cleared by writing 0 to the flag after reading it as 1. If the Vcc voltage level is equal to or lower than the LVD2 detection level (Vdet2) at this point, the RSTSR.LVD2F flag cannot be cleared. After 0 has been written to the RSTSR.LVD2F flag, reading 0 from the RSTSR.LVD2F flag will ensure that Vcc is higher than Vdet2.
The voltage-monitoring interrupts are classified as non-maskable interrupts. For details of interrupt processing, see section 11, Interrupt Controller (ICU).

Figure 7.5 shows the procedure for setting the voltage-monitoring interrupt.



Notes: 1. For the electrical characteristics, see section 33, Electrical Characteristics.
2. V_{POR} indicates the power-on reset detection level.
3. When the RSTSR.LVD2F flag cannot be cleared despite Vcc being at a higher electrical potential than Vdet2, the voltage detection circuit is in the stabilization wait state.
Clear the flag again after the specified stabilization time (t_{POR}) has elapsed.

Figure 7.4 Timing of Voltage-Monitoring Interrupt (Interrupt Selected in LVD2, Reset Selected in LVD1)

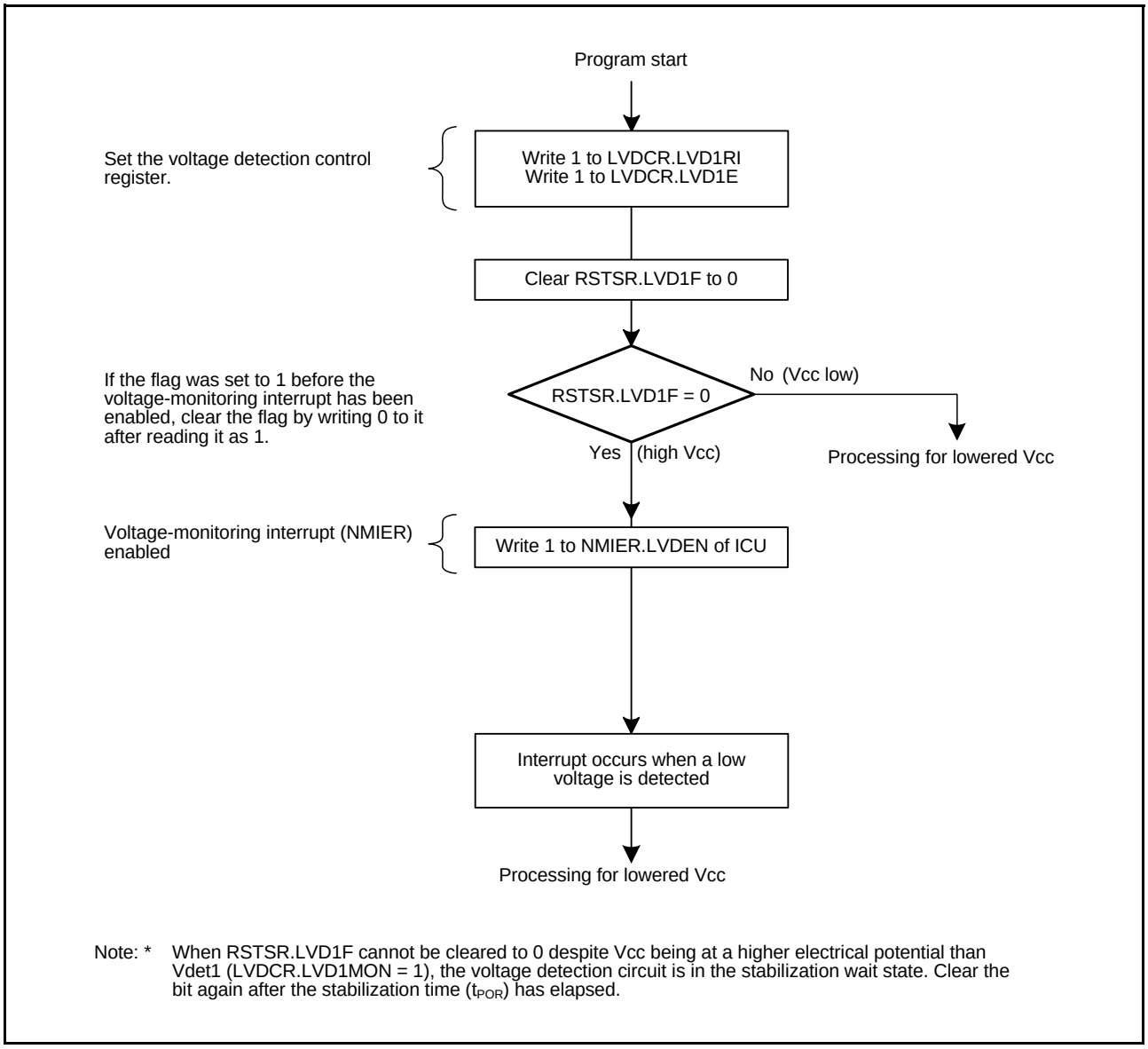


Figure 7.5 Example of Procedure for Setting Voltage-Monitoring Interrupt

7.3.3 Cancellation of Deep Software Standby Mode by the Voltage Detection Circuit

The RSTSR.LVD1F flag is set to 1 if Vcc falls to or below Vdet1 in deep software standby mode. At this time, if the LVDCR.LVD1E, LVDCR.LVD1RI, and DPSIER.DLVDE bits are all set to 1, the DPSIFR.DLVDF flag is set to 1 and the voltage detection circuit requests release from deep software standby mode.
Likewise, the RSTSR.LVD2F flag is set to 1 if Vcc falls to or below Vdet2 in deep software standby mode. At this time, if the LVDCR.LVD2E, LVDCR.LVD2RI, and DPSIER.DLVDE bits are all set to 1, the DPSIFR.DLVDF flag is set to 1 and the voltage detection circuit requests release from deep software standby mode.
For the deep software standby mode, see section 9, Low Power Consumption.

8. Clock Generation Circuit

8.1 Overview

The RX62T Group has a clock generation circuit that generates the system clock (ICLK), peripheral module clock (PCLK), and on-chip oscillator clock (IWDTCLK) signals.
The clock generation circuit consists of a main clock oscillator, IWDT-dedicated low-speed on-chip oscillator, oscillation stop detection circuit, internal oscillation circuit, phase-locked loop (PLL) circuit, frequency divider, and selector.
Table 8.1 lists the specifications of the clock generation circuit. Figure 8.1shows a block diagram of the clock generation circuit.

Table 8.1 Specifications of Clock Generation Circuit

Item	Specification
Use	• Generates the system clock (ICLK) to be supplied to the CPU, DTC, MTU3, GPT, ROM, and RAM. • Generates the peripheral module clock (PCLK) to be supplied to peripheral modules. • Generates the on-chip oscillator clock (IWDTCLK) to be supplied to the IWDT
Operating frequency	ICLK: 8 MHz to 100 MHz PCLK: 8 to 50 MHz IWDTCLK: 125 kHz (Typ.) Restrictions for setting clock frequencies: ICLK ≥ PCLK
Connectable resonator or additional circuit	Crystal resonator
Pins for connection to the resonator or additional circuit	Main clock: EXTAL, XTAL
Input clock (EXTAL) frequency	8 to 12.5 MHz
Selection of ICLK or PCLK	• The ICLK and PCLK are independently selectable as EXTAL × 8, × 4, × 2, and × 1
Oscillation stop detection function	• Switches to internal oscillation upon detection of main clock oscillator stop • Sets the MTU3 and GPT pins to the high-impedance state

Note: • For details, see section 33, Electrical Characteristics.

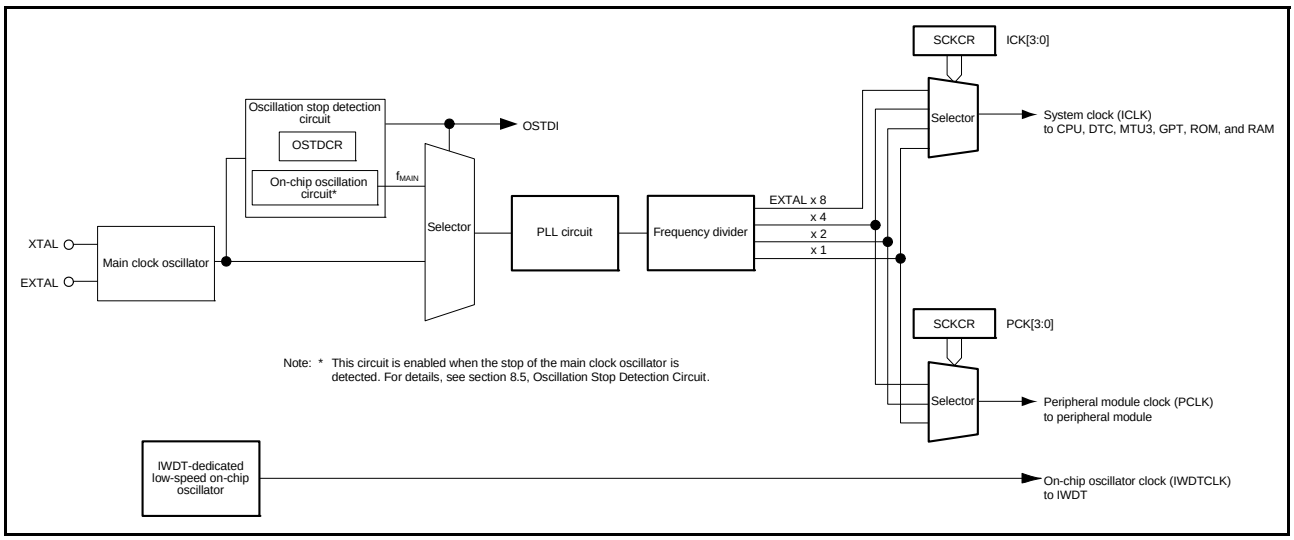


Figure 8.1 Block Diagram of Clock Generation Circuit

Table 8.2 lists the input/output pins of the clock generation circuit.

Table 8.2 Pin Configuration

Pin Name	I/O	Description
XTAL	Output	These pins are used to connect a crystal resonator. The EXTAL pin can also be used to input an external clock. For details, see Figure 8.3.2, External Clock Input.
EXTAL	Input	

8.2 Register Descriptions

Table 8.3 shows the register of the clock generation circuit.

Table 8.3 Register of Clock Generation Circuit

Register Name	Symbol	Value after Reset	Address	Access Size
System clock control register	SCKCR	0202 0200h	0008 0020h	32
Oscillation stop detection control register	OSTDCR	0080h	0008 0040h	16

8.2.1 System Clock Control Register (SCKCR)

Address: 0008 0020h

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
	—	—	—	—	ICK[3:0]				—	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	PCK[3:0]				—	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b7 to b0	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W
b11 to b8	PCK[3:0]*1	Peripheral Module Clock Select	b11b8 0 0 0 1: ×4 0 0 1 0: ×2 0 0 1 1: ×1 Settings other than those listed above are prohibited.	R/W
b16 to b12	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W
b17	—	Reserved	This bit is always read as 1. The write value should be 1.	R/W
b23 to b18	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W
b27 to b24	ICK[3:0]*2	System Clock Select	b27b24 0 0 0 0: ×8 0 0 0 1: ×4 0 0 1 0: ×2 0 0 1 1: ×1 Settings other than those listed above are prohibited.	R/W
b31 to b28	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W

Note 1. Do not set a frequency higher than the system clock (ICLK). If such a frequency is set, the clock frequency will be the same as the ICLK.

Note 2. Do not set a frequency lower than the peripheral module clock (PCLK). If such a frequency is set, the frequency of the PCLK will change to the system clock (ICLK) frequency.

SCKCR is used to select the frequencies of the system clock (ICLK) and peripheral module clock (PCLK).

PCK[3:0] Bits (Peripheral Module Clock Select)

These bits select the PCLK frequency.

The value of these bits indicates a multiplication factor of the input clock (EXTAL).

ICK[3:0] Bits (System Clock Select)

These bits select the frequency of the system clock (ICLK).
The value of these bits indicates a multiplication factor of the input clock (EXTAL).

8.2.2 Oscillation Stop Detection Control Register (OSTDCR)

Address: 0008 0040h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	KEY[7:0]								OSTDE	OSTDF	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b5 to b0	—	Reserved	These bits are always read as 0. The write value should be 0.	R
b6	OSTDF	Oscillation Stop Detection Flag	When OSTDE = 1: 0: The main clock oscillator is operating normally. 1: The stop of the main clock oscillator is detected. When OSTDE = 0: This bit is read as 0.	R
b7	OSTDE	Oscillation Stop Detection Function Enable	0: Oscillation stop detection function is disabled. 1: Oscillation stop detection function is enabled.	R/W
b15 to b8	KEY[7:0]	OSTDCR Key Code	ACh: Writing to OSTDCR is enabled. Other than above: Writing to OSTDCR is disabled. This bit is read as 0.	R/W

OSTDCR is used to control the oscillation stop detection function.

OSTDF Flag (Oscillation Stop Detection Flag)

This flag indicates the state of the main clock oscillator.
When the OSTDF flag is 1, this indicates that the stop of the main clock oscillator is detected.

OSTDE Bit (Oscillation Stop Detection Function Enable)

This bit enables or disables the oscillation stop detection function.
When the OSTDE bit is 1 (oscillation stop detection function is enabled), transitions to software standby mode or deep software standby mode are not possible. To make a transition to software standby mode or deep software standby mode, issue a WAIT instruction after setting the OSTDE bit to 0.

KEY[7:0] Bits (OSTDCR Key Code)

These bits are used to enable or disable writing to OSTDCR.
When writing a value to the OSTDE bit, set the KEY[7:0] bits to ACh before writing. If the KEY[7:0] bits are set to a value other than ACh, the OSTDE bit will not be changed even though OSTDCR is written to.

8.3 Main Clock Oscillator

Clock pulses can be supplied by connecting a crystal resonator or by inputting an external clock.

8.3.1 Connecting a Crystal Resonator

Figure 8.2shows an example of connecting a crystal resonator.Table 8.4 shows reference values of the damping resistance (Rd).
When supplying the clock from the crystal resonator, the frequency of the resonator should be in the range of 8 to 12.5 MHz.

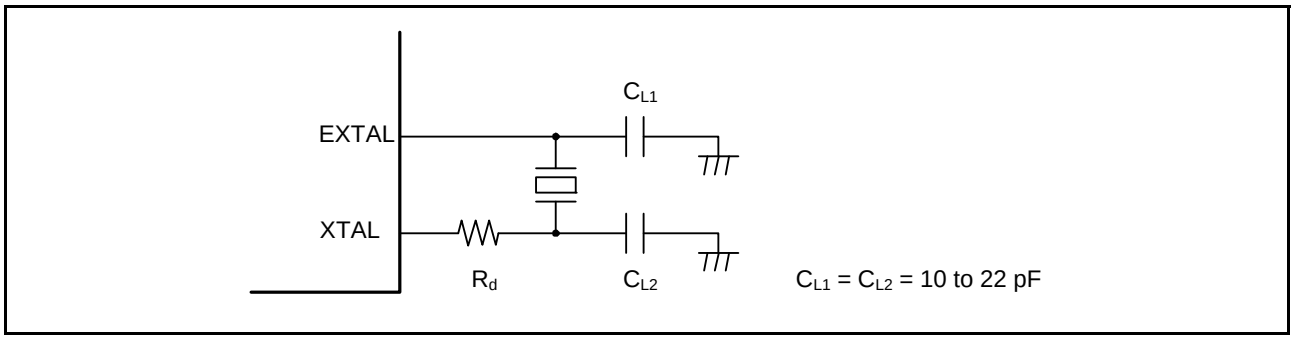


Figure 8.2 Example of Crystal Resonator Connection

Table 8.4 Damping Resistance (Reference Values)

Frequency (MHz)	8	10	12.5
Rd (Ω)	200	100	0

Figure 8.3shows an equivalent circuit of the crystal resonator. Use a crystal resonator that has the characteristics shown in Table 8.5.

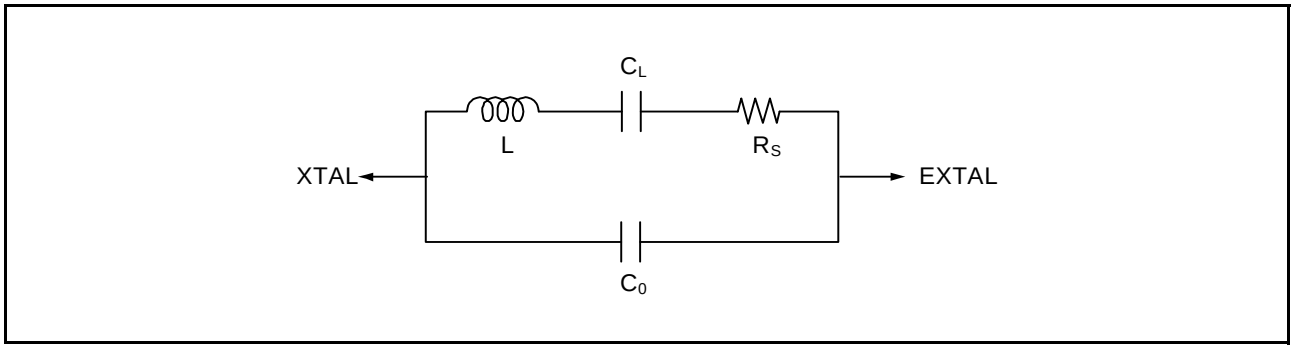


Figure 8.3 Equivalent Circuit of Crystal Resonator

Table 8.5 Crystal Resonator Characteristics (Reference Values)

Frequency (MHz)	8	10	12.5
R_S max (Ω)	80	70	60
C_0 max (pF)	7	7	7

8.3.2 External Clock Input

Figure 8.4 shows examples of external clock input. To leave the XTAL pin open, make the parasitic capacitance less than 10 pF. When the counter-phase clock is input to the XTAL pin, hold the external clock in high level during standby mode.

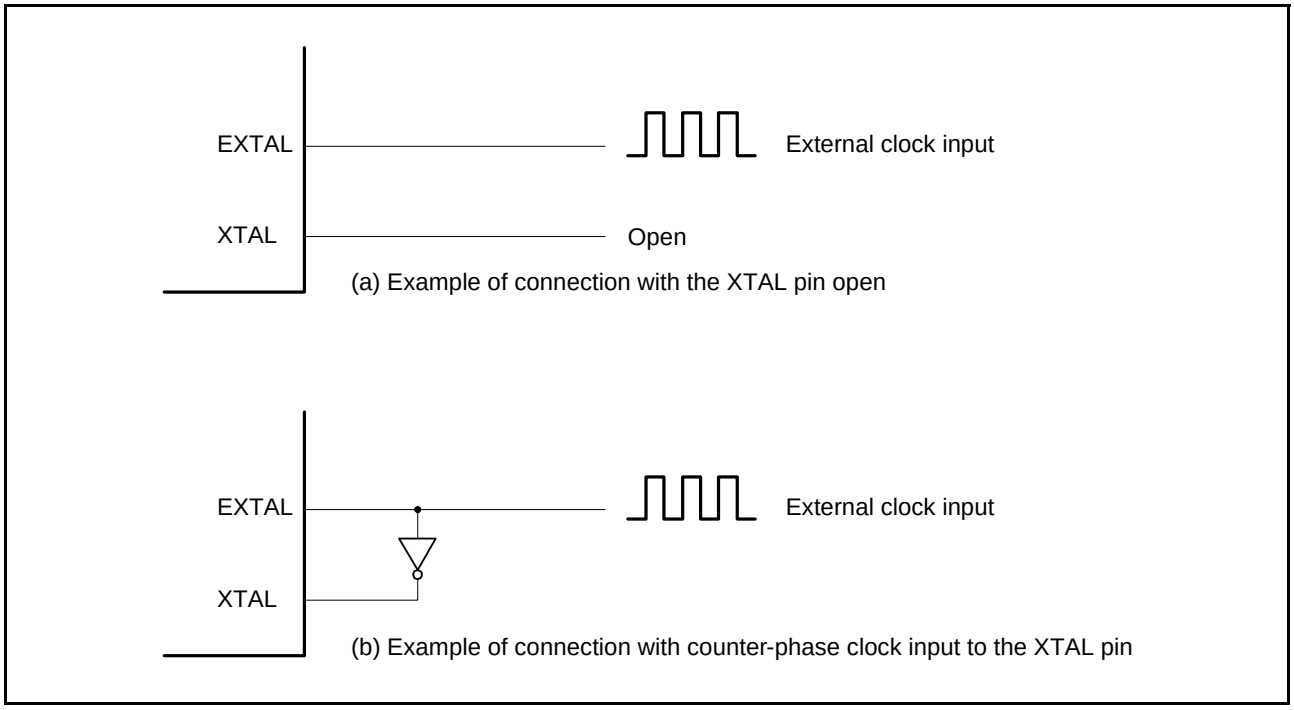


Figure 8.4 Examples of External Clock Input

8.4 IWDT-Dedicated Low-Speed On-Chip Oscillator

The IWDT-dedicated low-speed on-chip oscillator generates the on-chip oscillator clock (IWDTCLK) by the internal oscillation.

8.5 Oscillation Stop Detection Circuit

The oscillation stop detection circuit is able to detect the stop of the main clock oscillator and supply the internal oscillation clock that is output by the internal oscillation circuit, instead of the main clock.
For details, see section 8.10, Oscillation Stop Detection Function.

8.6 Internal Oscillation Circuit

The internal oscillation circuit generates the internal oscillation clock by the internal oscillation.

8.7 PLL Circuit

The PLL circuit has a function to multiply the frequency from the oscillator by a factor of 8.

8.8 Frequency Divider

The frequency divider divides the PLL clock to generate 1/2, 1/4, or 1/8 clock. After the ICK[3:0] and PCK[3:0] bits in SCKCR are updated, the RX62T operates with the updated frequencies.

8.9 Internal Clock

An internal clock is generated by multiplying the external input clock (EXTAL) by 8 with the PLL circuit, and then dividing the multiplied clock by 1, 2, 4, or 8 with the frequency divider. Other internal clocks are generated with internal oscillation in the IWDT-dedicated low-speed on-chip oscillator.
There are the following three types of internal clock.

- Operating clock of the CPU, DTC, MTU3, GPT, ROM, and RAM: System clock (ICLK)
- Operating clock of peripheral modules: Peripheral module clock (PCLK)
- Operating clock for the IWDT: On-chip oscillator clock (IWDTCLK)

The frequencies of these clocks are set by the combinations of bits ICK[3:0] and PCK[3:0] in SCKCR.

8.9.1 System Clock (ICLK)

The system clock (ICLK) is used as the operating clock of the CPU, DTC, MTU3, GPT, ROM, and RAM.
The ICLK frequency is specified by the ICK[3:0] bits in SCKCR.
A frequency lower than the peripheral module clock (PCLK) should not be set for the ICLK. If such a frequency is set, though the ICLK settings are enabled, the clock frequency of the PCLK will be the same as the ICLK.

8.9.2 Peripheral Module Clock (PCLK)

The peripheral module clock (PCLK) is the operating clock for peripheral modules.
The PCLK frequency is specified by the PCK[3:0] bits in SCKCR.
A frequency higher than the system clock (ICLK) should not be set for the PCLK. If such a frequency is set, the clock frequency will be the same as the ICLK.

8.9.3 On-Chip Oscillator Clock (IWDTCLK)

The on-chip oscillator clock (IWDTCLK) is the operating clock for the IWDT.
IWDTCLK is a clock generated by internal oscillation in the on-chip oscillator.
The IWDTCLK cycles are measured by the LOCO count function in the GPT. For details, see section 18.6, LOCO Count Function.

8.10 Oscillation Stop Detection Function

8.10.1 Detection of Oscillation Stop and Operation after the Detection

The oscillation stop detection function is used to detect termination of the main clock oscillator. After oscillation stop has been detected, the oscillation stop detection circuit is able to supply the internal oscillation clock that is output by the internal oscillation circuit, instead of the main clock. An oscillation stop interrupt request can be generated when oscillation stop has been detected. Also, the MTU3 and GPT output can be forcibly set to the high-impedance state when oscillation stop has been detected. For details on the MTU output, refer to section 16, Multi-Function Timer Pulse Unit 3 (MTU3), section 17, Port Output Enable 3 (POE3), section 18, General PWM Timer (GPT), and section Appendix 1., Port States in Each Processing Mode.

The RX62T Group detects that the main clock has stopped when the input clock is kept at 0 or 1 for a certain period (see section 33, Electrical Characteristics due to an error in the main clock oscillator or another reason.

When oscillation stop has been detected, the RX62T Group continues to operate on the internal oscillation clock that is output from the internal oscillation circuit.

For the frequency of the system clock (ICLK) during operation on the internal oscillation clock, see Table 8.6.

Table 8.6 System Clock (ICLK) Frequency when Internal Oscillation Circuit is Used

System Clock (ICLK)	Min.	Typ.	Max.
ICLK frequency (x 8)	8 x f_{MAIN}	8 x f_{MAIN}	8 x f_{MAIN}
ICLK frequency (x 4)	4 x f_{MAIN}	4 x f_{MAIN}	4 x f_{MAIN}
ICLK frequency (x 2)	2 x f_{MAIN}	2 x f_{MAIN}	2 x f_{MAIN}
ICLK frequency (x 1)	f_{MAIN}	f_{MAIN}	f_{MAIN}

Note: • For details on f_{MAIN}, see section 33, Electrical Characteristics.

The operating clock is automatically switched from the main clock to the internal oscillator when stoppage of oscillation is detected. Even if the main clock oscillator resumes operation after stoppage of oscillation has been detected, the internal oscillator will provide the operating clock for the LSI. However, the operating clock is switched from the internal oscillator to the main clock only during reset processing of pin resets, power-on resets, and voltage monitoring resets. Accordingly, the operating clock for the LSI will be the main clock once oscillation of the main clock oscillator has started.

The oscillation stop detection function is enabled immediately after the LSI has been internally initialized by all resets. To disable this function, clear the OSTDCR.OSTDE bit to 0. In addition, when the oscillation stop is detected and the LSI is operating on the internal oscillation clock, the OSTDCR.OSTDE bit cannot be cleared to 0.

8.10.2 Oscillation Stop Detection Interrupt

When the oscillation stop detection function is enabled, an oscillation stop detection interrupt request (OSCERI) is generated when oscillation stop is detected. The oscillation stop detection interrupt is a non-maskable interrupt. Since non-maskable interrupts are disabled in the initial state after the reset state is canceled, enable non-maskable interrupts through software when using the oscillation stop detection interrupt. For details, refer to section 11, Interrupt Controller (ICU).

The state in which the internal oscillation clock is operating due to oscillation stop detection means that an error has occurred in the system. In this state, take only emergency measures to solve the error.

8.10.3 Note on Release from Deep Software Standby Mode

If the main clock oscillator does not operate normally due to error occurrence while the chip is in deep software standby mode, interrupt-driven release from deep software standby mode might be impossible.

However, a pin reset will release the chip from deep software standby mode even if the main clock oscillator is not operating. Use a pin reset if release from deep software standby mode must be ensured.

8.11 Usage Notes

8.11.1 Notes on Clock Generation Circuit

1. The frequencies of the system clock (ICLK) and peripheral module clock (PCLK), supplied to each module change according to the setting of SCKCR. Select each frequency that is within the operation guaranteed range of clock cycle time (tcyc) specified in AC characteristics of electrical characteristics. Each frequency should meet the following:

   ICLK = 8 MHz to 100 MHz
   PCLK = 8 MHz to 50 MHz

2. All peripheral modules (except for the DTC, MTU3, and GPT) operate on the PCLK. Note therefore that the operating speed of modules such as the timer and SCI varies before and after the frequency is changed.
   In addition, the waiting time for canceling software standby mode varies with the PCLK frequency change. For details, see section 9.5.3.3, Setting Oscillation Settling Time after Software Standby Mode is Canceled.
3. The relationship between the system clock (ICLK) and peripheral module clock (PCLK) is ICLK ≥ PCLK, and the ICLK has the highest priority. For this reason, if a setting that does not meet these conditions is made, the PCLK may have the clock frequency set by the ICK[3:0] bits in SCKCR regardless of the settings of the PCK[3:0] bits in SCKCR.
4. After writing to the SCKCR, further writing to the same register before completion of the change in frequency is ignored. In the case of continued writing to the SCKCR, confirm that values read from the SCKCR are actually the most recently written values.
5. After writing to the SCKCR, transitions to software standby mode are prohibited until completion of the change in frequency. Subsequent operation is not guaranteed if a transition to software standby mode is attempted while the frequency is being changed. The interval between writing to the SCKCR and issuing of the WAIT instruction must take up at least 11 cycles of the system clock. For details, see section 5, I/O Registers.

8.11.2 Notes on Resonator

Since various resonator characteristics relate closely to the user's board design, adequate evaluation is required on the user side before use, referencing the resonator connection example shown in this section. The circuit constants for the resonator depend on the resonator to be used and the stray capacitance of the mounting circuit. Therefore, the circuit constants should be determined in full consultation with the resonator manufacturer. The voltage to be applied between the resonator pins must be within the absolute maximum rating.

8.11.3 Notes on Board Design

When using a crystal resonator, place the resonator and its capacitors as close to the XTAL and EXTAL pins as possible. Other signal lines should be routed away from the oscillation circuit as shown in Figure 8.5 to prevent electromagnetic induction from interfering with correct oscillation.
The XTAL pin and the reset pin are crossly arranged on the RX62T Group. Therefore, to avoid the reference from the clock signal, the reset signal should be guarded by GND.

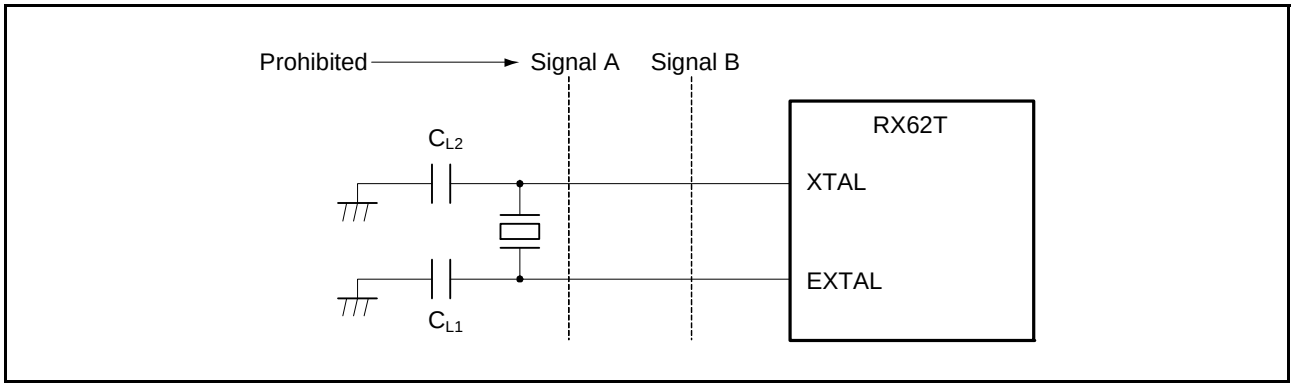


Figure 8.5 Notes on Board Design for Oscillation Circuit

Figure 8.6 shows a recommended external circuit for the PLL circuit. Separate pins PLLVcc and PLLVss from the other Vcc and Vss lines at the board power supply source, and be sure to insert bypass capacitors CPB and CB close to the pins. The pins PLLVcc and Vcc should be set to the same potential.

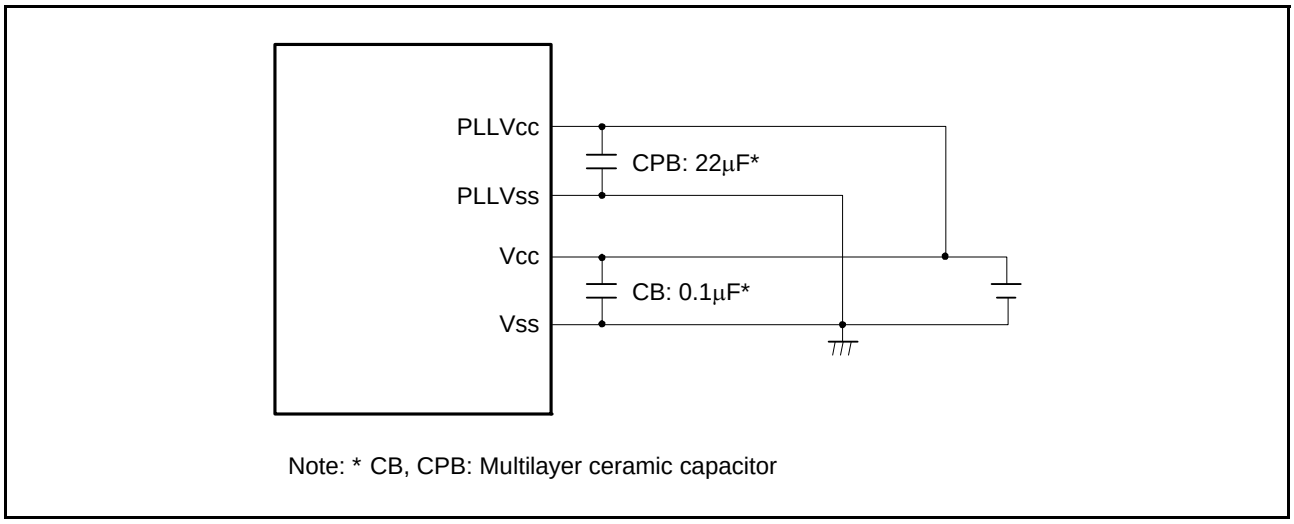


Figure 8.6 Recommended External Circuit for PLL Circuit

9. Low Power Consumption

9.1 Overview

The RX62T Group has functions to reduce power consumption, including a multi-clock function, module stop function, and a function for transition to low power consumption mode.

Table 9.1 shows the specifications of low power consumption function, and Table 9.2 shows the conditions to shift to low power consumption mode, states of the CPU and peripheral modules, and mode canceling method. After the reset state, this LSI enters the normal program execution state, but modules except the DTC do not operate.

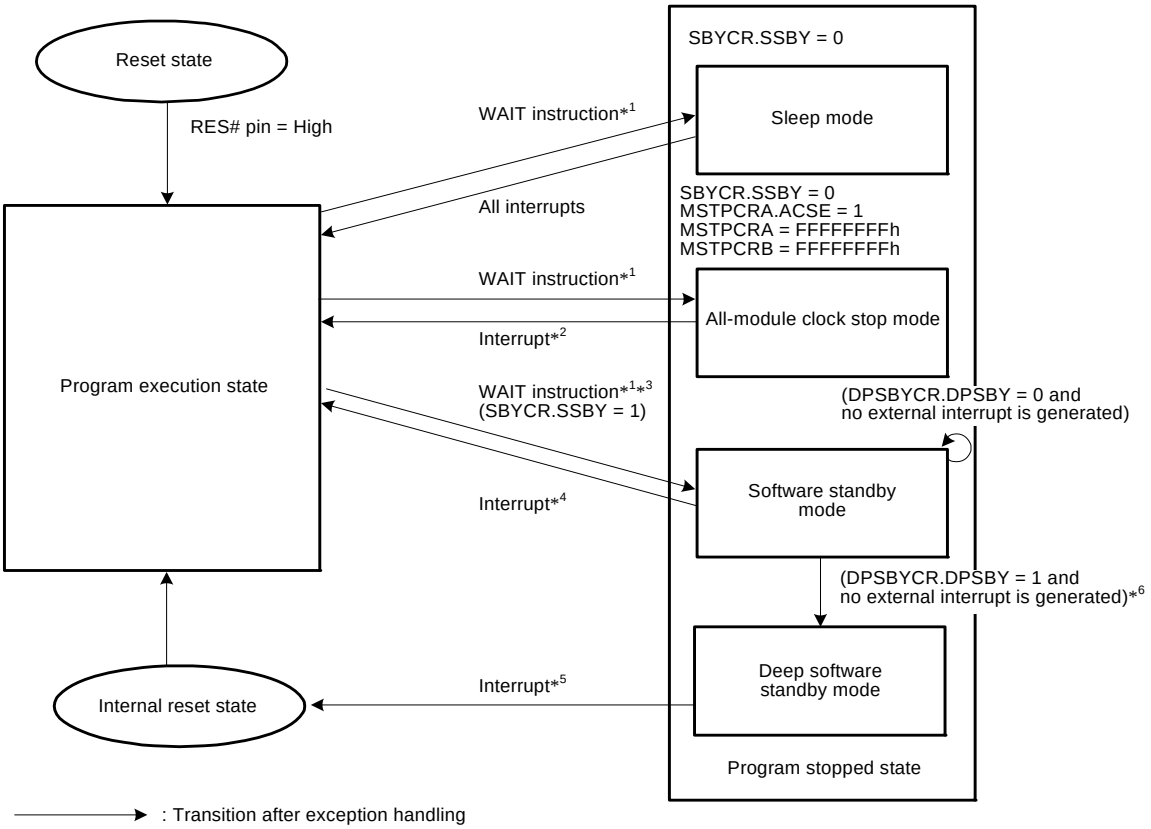
Table 9.1 Specifications of Low Power Consumption Function

Item	Specification
Multi-clock function	The frequency division ratio is settable independently for the system clock (ICLK) and peripheral module clock (PCLK)
Module stop function	Functions can be stopped independently for each peripheral module.
Function for transition to low power consumption mode	Transition to low power consumption mode is enabled to stop the CPU, peripheral modules, and oscillator.
Four low power consumption modes	Sleep mode All-module clock stop mode Software standby mode Deep software standby mode

Table 9.2 Transition and Cancellation of the Mode and the State of Operation

Transition and Cancellation of the Mode and the State of Operation	Sleep Mode	All-Module Clock Stop Mode	Software Standby Mode	Deep Software Standby Mode
Transition method	Control register + instruction	Control register + instruction	Control register + instruction	Control register + instruction
Canceling method other than resets	Interrupt	Interrupt*1	Interrupt*2	Interrupt*3
State after cancellation*4	Program execution state (interrupt processing)	Program execution state (interrupt processing)	Program execution state (interrupt processing)	Program execution state (reset processing)
Oscillator	Operating	Operating	Stopped	Stopped
CPU	Stopped (Retained)	Stopped (Retained)	Stopped (Retained)	Stopped (Undefined)
On-chip RAM (0000 0000h to 0000 3FFFh)	Operating (Retained)	Stopped (Retained)	Stopped (Retained)	Stopped (Undefined)
Watchdog timer (WDT)	Operating	Operating	Stopped (Retained)	Stopped (Undefined)
Independent watchdog timer (IWDT)	Operating	Operating	Stopped (Retained)	Stopped (Undefined)
Voltage detection circuit	Operating	Operating	Operating	Operating
Power-on reset circuit	Operating	Operating	Operating	Operating
Peripheral modules	Operating	Stopped*5	Stopped*5	Stopped (Undefined)
I/O pin state	Operating	Retained	Retained	Retained

Note: • "Stopped (Retained)" means that internal register values are retained and internal operations are suspended.
"Stopped (Undefined)" means that internal register values are undefined and power is not supplied to the internal circuit.
Note 1. An external interrupt or some internal interrupts (WDT, oscillation stop detection, and voltage monitoring).
Note 2. An external interrupt or some internal interrupts (voltage monitoring).
Note 3. NMI, IRQ0-A and IRQ1-A, or some internal interrupts (voltage monitor circuit). These interrupts are enabled only when the corresponding bit in DPSIER is set to 1.
Note 4. Cancellation by the RES# pin, power-on reset, voltage monitoring reset, watchdog timer reset, or independent watchdog timer reset is excluded. When canceled by the RES# pin, power-on reset, voltage monitoring reset, watchdog timer reset, or independent watchdog timer reset, this LSI enters the reset state.
Note 5. Peripheral modules retain the state.



Notes: 1. If an interrupt that becomes a canceling source is accepted while making a transition to the program stop state after the WAIT instruction has been executed, the transition to the program stop state is canceled and the interrupt exception handling is executed.

2. External interrupts and some internal interrupts (WDT, oscillation stop detection, and voltage monitoring).

3. Transitions to the software standby mode do not occur in the following cases.
   - The WDT is in use in watchdog timer mode.
   - The IWDT is in use.
   - The oscillation stop detection function is enabled.

4. External interrupts and some internal interrupts (voltage monitoring).

5. External interrupts (NMI, and IRQ0-A and IRQ1-A) and some internal interrupts (voltage monitor). However, these sources are enabled only when the corresponding bit in DPSIER is 1.

6. If a conflict between a transition to deep software standby mode and generation of software standby mode canceling source occurs, a mode transition may be made from software standby mode to program execution state through the interrupt exception handling. In this case, transition to deep software standby mode does not occur. For details, see section 9.7, Usage Notes.

7. An internal reset (deep software standby reset) follows the generation of an interrupt request as in point 5 above for the Time specified by the DPSWCR.WTSTS[5:0] bits. Release from deep software standby accompanies release from the Internal reset state. On release from the deep software standby state, the chip enters the program-execution state and starts reset exception processing.

When a pin reset, power-on reset, voltage monitor reset, watchdog timer reset, or independent watchdog timer reset is generated in any state, a transition to the reset state is made.

Figure 9.1 Mode Transitions

9.2 Register Descriptions

Table 9.3 is the list of low power consumption registers. For details on the system clock control register (SCKCR), see section 9.2.1, Standby Control Register (SBYCR).

Table 9.3 List of Low Power Consumption Registers (1 / 2)

Register Name	Symbol	Value after Reset	Address	Access Size
Standby control register	SBYCR	4F00h	0008 000Ch	16
Module stop control register A	MSTPCRA	4xFF FFFFh	0008 0010h	32
Module stop control register B	MSTPCRB	FFFF FFFFh	0008 0014h	32
Module stop control register C	MSTPCRC	FFFF 0000h	0008 0018h	32
Deep standby control register	DPSBYCR	31h	0008 C280h	8
Deep standby wait control register	DPSWCR	0Fh	0008 C281h	8
Deep standby interrupt enable register	DPSIER	00h	0008 C282h	8
Deep standby interrupt flag register	DPSIFR	00h	0008 C283h	8
Deep standby interrupt edge register	DPSIEGR	00h	0008 C284h	8
Reset status register	RSTSR	x000 0xxxb	0008 C285h	8
Deep standby backup register 0	DPSBKR0	xxh*	0008 C290h	8
Deep standby backup register 1	DPSBKR1	xxh*	0008 C291h	8
Deep standby backup register 2	DPSBKR2	xxh*	0008 C292h	8
Deep standby backup register 3	DPSBKR3	xxh*	0008 C293h	8
Deep standby backup register 4	DPSBKR4	xxh*	0008 C294h	8
Deep standby backup register 5	DPSBKR5	xxh*	0008 C295h	8
Deep standby backup register 6	DPSBKR6	xxh*	0008 C296h	8
Deep standby backup register 7	DPSBKR7	xxh*	0008 C297h	8
Deep standby backup register 8	DPSBKR8	xxh*	0008 C298h	8
Deep standby backup register 9	DPSBKR9	xxh*	0008 C299h	8
Deep standby backup register 10	DPSBKR10	xxh*	0008 C29Ah	8
Deep standby backup register 11	DPSBKR11	xxh*	0008 C29Bh	8
Deep standby backup register 12	DPSBKR12	xxh*	0008 C29Ch	8
Deep standby backup register 13	DPSBKR13	xxh*	0008 C29Dh	8
Deep standby backup register 14	DPSBKR14	xxh*	0008 C29Eh	8
Deep standby backup register 15	DPSBKR15	xxh*	0008 C29Fh	8
Deep standby backup register 16	DPSBKR16	xxh*	0008 C2A0h	8
Deep standby backup register 17	DPSBKR17	xxh*	0008 C2A1h	8
Deep standby backup register 18	DPSBKR18	xxh*	0008 C2A2h	8
Deep standby backup register 19	DPSBKR19	xxh*	0008 C2A3h	8
Deep standby backup register 20	DPSBKR20	xxh*	0008 C2A4h	8
Deep standby backup register 21	DPSBKR21	xxh*	0008 C2A5h	8
Deep standby backup register 22	DPSBKR22	xxh*	0008 C2A6h	8
Deep standby backup register 23	DPSBKR23	xxh*	0008 C2A7h	8
Deep standby backup register 24	DPSBKR24	xxh*	0008 C2A8h	8
Deep standby backup register 25	DPSBKR25	xxh*	0008 C2A9h	8
Deep standby backup register 26	DPSBKR26	xxh*	0008 C2AAh	8
Deep standby backup register 27	DPSBKR27	xxh*	0008 C2ABh	8
Deep standby backup register 28	DPSBKR28	xxh*	0008 C2ACh	8
Deep standby backup register 29	DPSBKR29	xxh*	0008 C2ADh	8
Deep standby backup register 30	DPSBKR30	xxh*	0008 C2AEh	8

Table 9.3 List of Low Power Consumption Registers (2 / 2)

Register Name	Symbol	Value after Reset	Address	Access Size
Deep standby backup register 31	DPSBKR31	xxh*	0008 C2AFh	8

Note: • DPSBKR0 to DPSBKR31 are not initialized and their values are undefined immediately after power-on.

9.2.1 Standby Control Register (SBYCR)

Address: 0008 000Ch

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	SSBY	—	—	STS[4:0]					—	—	—	—	—	—	—	—
Value after reset:	0	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b7 to b0	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b12 to b8	STS[4:0]	Standby Timer Select	b12b8 0 0 1 0 1: Waiting time = 64 states 0 0 1 1 0: Waiting time = 512 states 0 0 1 1 1: Waiting time = 1024 states 0 1 0 0 0: Waiting time = 2048 states 0 1 0 0 1: Waiting time = 4096 states 0 1 0 1 0: Waiting time = 16384 states 0 1 0 1 1: Waiting time = 32768 states 0 1 1 0 0: Waiting time = 65536 states 0 1 1 0 1: Waiting time = 131072 states 0 1 1 1 0: Waiting time = 262144 states 0 1 1 1 1: Waiting time = 524288 states Settings other than above are prohibited.	R/W
b13	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b14	—	Reserved	This bit is always read as 1. The write value should always be 1.	R/W
b15	SSBY	Software Standby	0: Shifts to sleep mode or all-module clock stop mode after the WAIT instruction is executed 1: Shifts to software standby mode after the WAIT instruction is executed	R/W

SBYCR is used to control software standby mode.

STS[4:0] Bits (Standby Timer Select)

These bits select the time for the RX62T Group to wait until the clock is stabilized when software standby mode is canceled by an external interrupt.

In the case of crystal oscillation, see Table 9.4 and make a selection according to the operating frequency so that the waiting time is no less than the oscillation settling time. When an external clock is used, the PLL circuit settling time is necessary. Select a waiting time referring to Table 9.4.

During the oscillation settling time, the standby timer is counted on the peripheral module clock (PCLK) frequency. Note this when the multi-clock function is in use.

SSBY Bit (Software Standby)

The SSBY bit specifies the transition destination after the WAIT instruction is executed.

When the SSBY bit is set to 0, the LSI enters either sleep mode or all-module clock stop mode after execution of the WAIT instruction, according to the setting of the MSTPCRA and MSTPCRB registers. When the SSBY bit is set to 1, the LSI enters software standby mode after execution of the WAIT instruction. In this case, when the DPSBY bit in DPSBYCR is 1, the LSI enters deep software standby mode after software standby mode. For details, see Table 9.5, Low Power Consumption Modes.

This bit is not cleared to 0 when software standby mode is canceled by an external interrupt and the LSI enters normal mode. Write 0 to this bit to clear.

When the WDT is used in watchdog timer mode, the IWDT is used, or the oscillation stop detection function is enabled, the setting of this bit is invalid and the LSI always enters sleep mode or all-module clock stop mode after the WAIT instruction is executed.

9.2.2 Module Stop Control Register A (MSTPCRA)

Address: 0008 0010h

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
	ACSE	—	—	MSTPA28	—	—	—	MSTPA24	MSTPA23	—	—	—	—	—	MSTPA17	MSTPA16
Value after reset:	0	1	0	0	0	x	1	1	0	1	1	1	1	1	1	1

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	MSTPA15	MSTPA14	—	—	—	—	MSTPA9	—	MSTPA7	—	—	—	—	—	—	—
Value after reset:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

x: Undefined

Bit	Symbol	Bit Name	Description	R/W
b6 to b0	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W
b7	MSTPA7	General PWM Timer Module Stop	Target module: GPT 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b8	—	Reserved	This bit is always read as 1. The write value should always be 1.	R/W
b9	MSTPA9	Multifunction Timer Pulse Unit 3 Module Stop	Target module: MTU3 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b13 to b10	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W
b14	MSTPA14	Compare Match Timer (Unit 1) Module Stop	Target module: CMT unit 1 (CMT2, CMT3) 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b15	MSTPA15	Compare Match Timer (Unit 0) Module Stop	Target module: CMT unit 0 (CMT0, CMT1) 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b16	MSTPA16	12-Bit A/D Converter (Unit 1) Module Stop	Target module: 12-bit A/D converter unit 1 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b17	MSTPA17	12-Bit A/D Converter (Unit 0) Module Stop	Target module: 12-bit A/D converter unit 0 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b22 to b18	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W
b23	MSTPA23 *1	10-Bit A/D Converter Module Stop	Target module: 10-bit AD converter 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b24	MSTPA24	12-Bit A/D Converter Control Section Module Stop	Target module: S12ADA control section 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b26 to b25	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W
b27	—	Reserved	This bit is always read as undefined. The write value should always be 1.	R/W
b28	MSTPA28	Data Transfer Controller Module Stop	Target module: DTC 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b29	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W

Bit	Symbol	Bit Name	Description	R/W
b30	—	Reserved	This bit is always read as 1. The write value should always be 1.	R/W
b31	ACSE *2	All-Module Clock Stop Mode Enable	0: All-module clock stop mode is disabled 1: All-module clock stop mode is enabled	R/W

Note 1. In the 64-pin version, this bit is reserved. It is always read as 1. The write value should be 1.
Note 2. When the SBYCR.SSBY bit is 0 and the MSTPCRA.ACSE bit is 0, shift to sleep mode after the WAIT instruction is executed.

MSTPCRA is used to control the module stop state.

ACSE Bit (All-Module Clock Stop Mode Enable)

The ACSE bit enables or disables all-module clock stop mode for reducing supply current by stopping the bus controller and I/O ports when the CPU executes the WAIT instruction after the module stop state has been specified for all modules controlled by MSTPCRA and MSTPCRB.

9.2.3 Module Stop Control Register B (MSTPCRB)

Address: 0008 0014h

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
	MSTPB31	MSTPB30	MSTPB29	—	—	—	—	—	MSTPB23	—	MSTPB21	—	—	——	MSTPB17	—
Value after reset:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	——	——	——	MSTPB7	——	—	—	—	—	—	MSTPB0
Value after reset:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Bit	Symbol	Bit Name	Description	R/W
b0	MSTPB0	CAN Module Stop*1	Target module: CAN 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b6 to b1	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W
b7	MSTPB7	LIN Module Stop	Target module: LIN 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b16 to b8	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W
b17	MSTPB17	Serial Peripheral Interface Module Stop	Target module: RSPI 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b20 to b18	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W
b21	MSTPB21	I^2C Bus Interface Module Stop	Target module: RIIC 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b22	—	Reserved	This bit is always read as 1. The write value should always be 1.	R/W
b23	MSTPB23	CRC Calculator Module Stop	Target module: CRC 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b28 to b24	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W
b29	MSTPB29	Serial Communication Interface 2 Module Stop	Target module: SCI2 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b30	MSTPB30	Serial Communication Interface 1 Module Stop	Target module: SCI1 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b31	MSTPB31	Serial Communication Interface 0 Module Stop	Target module: SCI0 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W

Note 1. In the product without the CAN function, this bit is reserved. It is always read as 1. The write value should be 1.

MSTPCRB is used to control the module stop state.

9.2.4 Module Stop Control Register C (MSTPCRC)

Address: 0008 0018h

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Value after reset:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	MSTPC0
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	MSTPC0*1	RAM Module Stop	Target module: RAM (0000 0000h to 0000 3FFFh) 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b15 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b31 to b16	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W

Note 1. The MSTPC0 bit should not be set to 1 during access to the on-chip RAM. The on-chip RAM should not be accessed with the MSTPC0 bit set to 1.

MSTPCRC is used to control the module stop state.

9.2.5 Deep Standby Control Register (DPSBYCR)

Address: 0008 C280h

	b7	b6	b5	b4	b3	b2	b1	b0
	DPSBY	IOKEEP	—	—	—	—	—	—
Value after reset:	0	0	1	1	0	0	0	1

Bit	Symbol	Bit Name	Description	R/W
b0	—	Reserved	This bit is always read as 1. The write value should always be 1.	R/W
b3 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b5, b4	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W
b6	IOKEEP	I/O Port Retention	0: Deep software standby mode and I/O port retention are canceled simultaneously 1: I/O port retention is canceled when 0 is written to the IOKEEP bit after deep software standby mode is canceled	R/W
b7	DPSBY	Deep Software Standby	SSBY b7 0 0: Transition to sleep mode or all-module clock stop mode is made after the WAIT instruction is executed 0 1: Transition to sleep mode or all-module clock stop mode is made after the WAIT instruction is executed 1 0: Transition to software standby mode is made after the WAIT instruction is executed 1 1: Transition to deep software standby mode is made after the WAIT instruction is executed	R/W

DPSBYCR is used to control deep software standby mode.
DPSBYCR is initialized by the reset signal from the RES# pin, a power-on reset, or a voltage monitoring reset, but is not initialized by the internal reset signal that cancels deep software standby mode.

IOKEEP Bit (I/O Port Retention)

In deep software standby mode, I/O ports keep retaining the same states from software standby mode. The IOKEEP bit specifies whether to keep retaining the I/O port states from deep software standby mode even after deep software standby mode is canceled, or to cancel retaining the I/O port states.

DPSBY Bit (Deep Software Standby)

The DPSBY bit controls transitions to deep software standby mode.
When the WAIT instruction is executed while the SSBY and DPSBY bits in SBYCR are 1, the LSI enters deep software standby mode through software standby mode.
This bit is not cleared to 0 when deep software standby mode is canceled by an external interrupt or an internal interrupt (voltage monitoring). Write 0 to this bit to clear.
The setting of this bit is invalid when the WDT is used in watchdog timer mode, the IWDT is used, or the oscillation stop detection function is enabled. In this case, even when the SSBY and DPSBY bits in SBYCR are set to 1, the LSI always enters sleep mode or all-module clock stop mode after the WAIT instruction is executed.

9.2.6 Deep Standby Wait Control Register (DPSWCR)

Address: 0008 C281h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	WTSTS[5:0]					
Value after reset:	0	0	0	0	1	1	1	1

Bit	Symbol	Bit Name	Description	R/W
b5 to b0	WTSTS[5:0]	Deep Software Standby Waiting Time	b5 b0 0 0 0 1 0 1: Waiting time = 64 states 0 0 0 1 1 0: Waiting time = 512 states 0 0 0 1 1 1: Waiting time = 1024 states 0 0 1 0 0 0: Waiting time = 2048 states 0 0 1 0 0 1: Waiting time = 4096 states 0 0 1 0 1 0: Waiting time = 16384 states 0 0 1 0 1 1: Waiting time = 32768 states 0 0 1 1 0 0: Waiting time = 65536 states 0 0 1 1 0 1: Waiting time = 131072 states 0 0 1 1 1 0: Waiting time = 262144 states 0 0 1 1 1 1: Waiting time = 524288 states	R/W
b7, b6	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

DPSWCR is used to select the time for the RX62T Group to wait until the clock is stabilized when deep software standby mode is canceled by an external interrupt or an internal interrupt (voltage monitoring).
DPSWCR is initialized by the reset signal from the RES# pin, a power-on reset, or a voltage monitoring reset, but is not initialized by the internal reset signal that cancels deep software standby mode.

WTSTS[5:0] Bits (Deep Software Standby Waiting Time)

These bits select the time for the RX62T Group to wait until the clock is stabilized when deep software standby mode is canceled by an external interrupt or an internal interrupt (voltage monitoring). When using deep software standby mode, set the WTSTS[5:0] bits before a transition to deep software standby mode is made.
In the case of crystal oscillation, see Table 9.4 and make a selection according to the operating frequency so that the waiting time is no less than the oscillation settling time. When an external clock is used, the PLL circuit settling time is necessary. Select a waiting time referring to Table 9.4.
During the oscillation settling time, the counter is counted on the EXTAL input clock frequency.

9.2.7 Deep Standby Interrupt Enable Register (DPSIER)

Address: 0008 C282h

	b7	b6	b5	b4	b3	b2	b1	b0
	DNMIE	—	—	DLVDE	—	—	DIRQ1E	DIRQ0E
Value after reset:	0	0	0	0	1	1	1	0

Bit	Symbol	Bit Name	Description	R/W
b0	DIRQ0E	IRQ0 Pin Enable	0: Canceling deep software standby mode by the IRQ0 pin is disabled 1: Canceling deep software standby mode by the IRQ0 pin is enabled	R/W
b1	DIRQ1E	IRQ1 Pin Enable	0: Canceling deep software standby mode by the IRQ1 pin is disabled 1: Canceling deep software standby mode by the IRQ1 pin is enabled	R/W
b3, b2	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b4	DLVDE	LVD Deep Standby Cancel Signal Enable	0: Canceling deep software standby mode by the voltage detection interrupt is disabled 1: Canceling deep software standby mode by the voltage detection interrupt is enabled	R/W
b6, b5	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7	DNMIE	NMI Pin Enable	0: Canceling deep software standby mode by the NMI pin is disabled 1: Canceling deep software standby mode by the NMI pin is enabled	R/(W)*1

Note 1. After this register has been initialized by the reset signal from the RES# pin, a power-on reset, or a voltage monitoring reset, 1 can be written only once. Once 1 is written to the DNMIE bit, subsequent write accesses are disabled.

DPSIER is used to enable or disable the external interrupt pin and internal cancellation signals that cancel deep software standby mode.

DPSIER is initialized by the reset signal from the RES# pin, a power-on reset, or a voltage monitoring reset, but is not initialized by the internal reset signal that cancels deep software standby mode.

Note that modifying the DPSIER register setting causes a change in the internal state of control over the input buffer of the corresponding pin. At that time, an edge might be generated internally according to the pin state, and if this happens, it leads to setting of the DPSIFR register value to 1. Before causing a shift to deep software standby mode, set the DPSIFR register value to 0.

Also note that the input buffer is disabled on a transition to deep software standby mode if the value of the DPSIER register is 0. At that time, an edge might be generated internally according to the pin state, and if this happens, it leads to setting of the DPSIFR register value to 1. In this case, however, if the DPSIEGR register value is 0, no rising edges are detected and thus the DPSIFR register value will not be 1.

9.2.8 Deep Standby Interrupt Flag Register (DPSIFR)

Address: 0008 C283h

	b7	b6	b5	b4	b3	b2	b1	b0
	DNMIF	—	—	DLVDF	—	—	DIRQ1F	DIRQ0F
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	DIRQ0F	IRQ0 Deep Standby Cancel Flag	0: No cancel request by the IRQ0 pin is generated 1: A cancel request by the IRQ0 pin is generated	R/(W)*1
b1	DIRQ1F	IRQ1 Deep Standby Cancel Flag	0: No cancel request by the IRQ1 pin is generated 1: A cancel request by the IRQ1 pin is generated	R/(W)*1
b3, b2	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/(W)
b4	DLVDF	LVD Deep Standby Cancel Flag	0: No cancel request by the voltage monitor signal is generated 1: A cancel request by the voltage monitor signal is generated	R/(W)*1
b6, b5	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/(W)
b7	DNMIF	NMI Deep Standby Cancel Flag	0: No cancel request by the NMI pin is generated 1: A cancel request by the NMI pin is generated	R/(W)*1

Note 1. Only 0 can be written to clear the flag.

DPSIFR is used to hold the request for canceling deep software standby mode.
Each flag is set to 1 when a cancel request specified by the deep standby interrupt edge register (DPSIEGR) is generated. Since each flag is set to 1 when a cancel request is generated in any mode, a transition to deep software standby mode should be made after DPSIFR is cleared to 0.
DPSIFR is initialized by the reset signal from the RES# pin, a power-on reset, or a voltage monitoring reset, but is not initialized by the internal reset signal that cancels deep software standby mode.

DIRQnF Flags (IRQn Deep Standby Cancel Flag) (n = 0, 1)

These flags indicate that a cancel request by the IRQn pin has been generated.
[Setting condition]

- A cancel request by the IRQn pin specified by DPSIEGR is generated

[Clearing condition]

- Each bit is read as 1 and then written by 0

DLVDF Flag (LVD Deep Standby Cancel Flag)

This flag indicates that a cancel request by the voltage monitor signal has been generated.
[Setting condition]

- A cancel request by the voltage monitor signal is generated

[Clearing condition]

- This bit is read as 1 and then written by 0

DNMIF Flag (NMI Deep Standby Cancel Flag)

This flag indicates that a cancel request by the NMI pin has been generated.

[Setting condition]

- A cancel request by the NMI pin specified by DPSIEGR is generated

[Clearing condition]

- This bit is read as 1 and then written by 0

9.2.9 Deep Standby Interrupt Edge Register (DPSIEGR)

Address: 0008 C284h

	b7	b6	b5	b4	b3	b2	b1	b0
	DNMIEG	—	—	—	—	—	DIRQ1EG	DIRQ0EG
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	DIRQ0EG	IRQ0 Edge Select	0: A cancel request is generated at a falling edge 1: A cancel request is generated at a rising edge	R/W
b1	DIRQ1EG	IRQ1 Edge Select	0: A cancel request is generated at a falling edge 1: A cancel request is generated at a rising edge	R/W
b6 to b2	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7	DNMIEG	NMI Edge Select	0: A cancel request is generated at a falling edge 1: A cancel request is generated at a rising edge	R/W

DPSIEGR is used to select an edge of the cancel signal for canceling deep software standby mode.

DPSIEGR is initialized by the reset signal from the RES# pin, a power-on reset, or a voltage monitoring reset, but is not initialized by the internal reset signal that cancels deep software standby mode.

9.2.10 Reset Status Register (RSTSR)

Address: 0008 C285h

	b7	b6	b5	b4	b3	b2	b1	b0
	DPSRSTF	—	—	—	—	LVD2F	LVD1F	PORF
Value after reset:	0/1*	0	0	0	0	0/1*	0/1*	0/1*

Note: * The initial value depends on reset generation sources.

Bit	Symbol	Bit Name	Description	R/W
b0	PORF	Power-On Reset Flag	0: A power-on reset is not generated. 1: A power-on reset is generated.	R
b1	LVD1F	LVD1 Detection Flag	0: LVD1 is not detected. 1: LVD1 is detected.	R/(W)*1
b2	LVD2F	LVD2 Detection Flag	0: LVD2 is not detected. 1: LVD2 is detected.	R/(W)*1
b6 to b3	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7	DPSRSTF	Deep Software Standby Reset Flag	0: A deep software standby mode canceling source is not generated by an external interrupt or an internal interrupt (voltage monitoring). 1: A deep software standby mode canceling source is generated by an external interrupt or an internal interrupt (voltage monitoring).	R/(W)*1

Note 1. Only 0 can be written to clear the flag.

RSTSR indicates an internal reset generation source.

PORF Flag (Power-On Reset Flag)

The PORF flag indicates that a power-on reset has been generated.
This flag is initialized by the reset signal from the RES# pin, but is not initialized by the internal reset signal that cancels deep software standby mode.
[Setting condition]

- A power-on reset is generated.

[Clearing condition]

- This bit is reset by the RES# pin.

LVD1F Flag (LVD1 Detection Flag)

The LVD1F flag indicates that a Vcc voltage lower than the Vdet1 level has been detected.
This flag is initialized by the reset signal from the RES# pin or a power-on reset, but is not initialized by the internal reset signal that cancels deep software standby mode.
[Setting condition]

- Vcc voltage equal to or lower than the Vdet1 level is detected.

[Clearing conditions]

- This bit is read as 1 and then written by 0 in a state where Vcc has exceeded Vdet1 and the settling time has passed, while the LVDCR.LVD1E bit is 1.
- A reset by the RES# pin is generated.
- A power-on reset is generated.

LVD2F Flag (LVD2 Detection Flag)

The LVD2F flag indicates that a Vcc voltage lower than the Vdet2 level has been detected.
This flag is initialized by the reset signal from the RES# pin or a power-on reset, but is not initialized by the internal reset signal that cancels deep software standby mode.
[Setting condition]

- Vcc voltage equal to or lower than the Vdet2 level is detected.

[Clearing conditions]

- This bit is read as 1 and then written by 0 in a state where Vcc has exceeded Vdet2 and the settling time has passed, while the LVDCR.LVD2E bit is 1.
- A reset by the RES# pin is generated.
- A power-on reset is generated.
- A reset by LVD1 is generated.

DPSRSTF Flag (Deep Software Standby Reset Flag)

The DPSRSTF flag indicates that deep software standby mode has been canceled by an external interrupt source specified by DPSIER and DPSIEGR or an internal interrupt (voltage monitoring), and an internal reset has been generated.
This flag is initialized by the reset signal from the RES# pin, a power-on reset, or a voltage monitoring reset, but is not initialized by the internal reset signal that cancels deep software standby mode.
[Setting condition]

- Deep software standby mode is canceled by an external interrupt source or an internal interrupt (voltage monitoring).

[Clearing conditions]

- This bit is read as 1 and then written by 0
- A reset by the RES# pin is generated.
- A power-on reset is generated.
- A reset by LVD1 is generated.
- A reset by LVD2 is generated.

9.2.11 Deep Standby Backup Register (DPSBKRy) (y = 0 to 31)

Address: 0008 C290h to 0008 C2AFh

	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	x	x	x	x	x	x	x	x

x: Undefined

DPSBKRy is a 32-byte readable/writable register to store data during deep software standby mode.
The value of this register is retained even in deep software standby mode where on-chip RAM data is not retained.
DPSBKRy is not initialized and the register value is undefined immediately after power-on.

9.3 Multi-Clock Function

When the ICK[3:0] and PCK[3:0] bits in SCKCR are set, the clock frequency changes.
The CPU and bus masters operate on the operating clock specified by the ICK[3:0] bits. Peripheral modules operate on the operating clock specified by the PCK[3:0] bits. For details, see section 8, Clock Generation Circuit.

9.4 Module Stop Function

The module stop function can be set for each on-chip peripheral module.
When the MSTPyj bit (y = A to C, j = 31 to 0) in MSTPCRA to MSTPCRC is set to 1, the specified module stops operating and enters the module stop state, but the CPU continues to operate independently. Clearing the MSTPyj bit to 0 cancels the module stop state, allowing the module to restart operating at the end of the bus cycle.
The internal states of modules are retained in the module stop state.
After a reset is released, all modules other than the DTC and on-chip RAM are placed in the module stop state. No read/write access can be made to the registers of the module that are in the module stop state.

9.5 Low Power Consumption Modes

9.5.1 Sleep Mode

9.5.1.1 Transition to Sleep Mode

When the WAIT instruction is executed while the SSBY bit in SBYCR is 0, the CPU enters sleep mode.
In sleep mode, the CPU stops operating but the contents of its internal registers are retained. Other peripheral functions do not stop.
When making a transition to sleep mode while WDT is used, WDT stops counting.
When sleep mode is used, execute a WAIT instruction after the following settings:

1. Set the PSW.I bit to 0.*1
2. Select the CPU as the receiver of interrupts to be used for return from sleep mode.
3. Set the priority level*2 of an interrupt to be used for return from sleep mode higher than the value of the PSW.IPL[2:0] bits*1 of the CPU
4. Set the IERm.IENj bit*2 of an interrupt to be used for return from sleep mode to 1.
5. Read the last I/O register to have been written to check that the new value has actually been reflected.
6. Execute a WAIT instruction (the PSW.I bit *1 of the CPU is automatically set to 1 due to the execution of a WAIT instruction).

Note 1. Refer to section 2, CPU for details.
Note 2. Refer to section 11, Interrupt Controller (ICU) for details.

9.5.1.2 Canceling Sleep Mode

Sleep mode is canceled by any interrupt, the reset signal from the RES# pin, a power-on reset, a voltage monitoring reset, a reset caused by a WDT overflow, or a reset caused by an IWDT underflow.

- Canceling by an interrupt
  When an interrupt occurs, sleep mode is canceled and the interrupt exception handling starts. If a maskable interrupt has been masked by the CPU (the priority level*1 of the interrupt has been set to a value lower than that of the IPL[3:0] bits*2 in PSW of the CPU), sleep mode is not canceled.
- Canceling by the RES# pin
  When the RES# pin is driven low, the LSI enters the reset state. When the RES# pin is driven high after the reset signal is input for a predetermined time period, the CPU starts the reset exception handling.
- Canceling by a WDT overflow reset
  Sleep mode is canceled by an internal reset generated by a WDT overflow.
- Canceling by an IWDT underflow reset
  Sleep mode is canceled by an internal reset generated by an IWDT underflow.
- Canceling by a voltage monitoring reset
  Sleep mode is canceled by a voltage monitoring reset from the voltage detection circuit.
- Canceling by a power-on reset
  Sleep mode is canceled by a power-on reset.

Note 1. For details, see section 11, Interrupt Controller (ICU).
Note 2. For details, see section 2, CPU.

9.5.2 All-Module Clock Stop Mode

9.5.2.1 Transition to All-Module Clock Stop Mode

When the following two conditions are satisfied, executing the WAIT instruction with the SSBY bit in SBYCR cleared to 0 will cause the transition to all-module clock stop mode at the end of the bus cycle.*1

- The ACSE bit in MSTPCRA is set to 1.
- All the modules controlled by the MSTPCRA and MSTPCRB registers are set in the module stop state (MSTPCRA and MSTPCRB = FFFFFFFFh).

In all-module clock stop mode, all modules (other than the WDT, IWDT, voltage detection circuit, and power-on reset circuit), the CPU, the bus controller, and the I/O ports are stopped.
If a further reduction in supply current is required beyond that in all-module clock stop mode, stop the target modules for which operation or stopping is controlled by MSTPCRC.
When all-module clock stop mode is in use, issue a WAIT instruction after making the following settings.

1. Clear the I bit*2 in PSW of the CPU to 0.
2. Set the interrupt destination to be used for recovery from all-module clock stop mode to the CPU.
3. Set the priority*3 of the interrupt to be used for recovery from all-module clock stop mode to a level higher than the setting of the IPL[3:0] bits*2 in PSW.
4. Set the IENn bit*3 in IERm for the interrupt to be used for recovery from all-module clock stop mode to 1.
5. Execute a WAIT instruction (executing a WAIT instruction causes automatic setting of the I bit*2 in PSW of the CPU to 1).

Note 1. Transitions to all-module clock stop mode are not be made in some states of DTC operations. Before setting the MSTPA28 bit in MSTPCRA to 1, clear the DTCST bit in DTCST of the DTC to 0 so that the DTC is not initiated.
Note 2. For details, see section 2, CPU.
Note 3. For details, see section 11, Interrupt Controller (ICU).

9.5.2.2 Canceling All-Module Clock Stop Mode

All-module clock stop mode is canceled by an external interrupt (the NMI pin or any pin from among IRQ0 to IRQ7), the reset signal from the RES# pin, a voltage monitoring reset, a power-on reset, or an internal interrupt (from the WDT, voltage detection circuit, or oscillation stop detection), and normal program execution resumes once handling of the given exception is complete. However, note that in cases where a maskable interrupt has been masked by the CPU (the priority level*1 of the interrupt has been set to a value lower than that of the IPL[3:0] bits*2 in PSW of the CPU) or a maskable interrupt has been set up as a trigger for transfer by the DTC, the interrupt will not trigger release from all-module clock stop mode.

Note 1. For details, see section 11, Interrupt Controller (ICU).
Note 2. For details, see section 2, CPU.

9.5.3 Software Standby Mode

9.5.3.1 Transition to Software Standby Mode

When the WAIT instruction is executed with the SSBY bit in SBYCR set to 1 and the DPSBY bit in DPSBYCR cleared to 0, a transition to software standby mode is made. In this mode, the CPU, on-chip peripheral functions, and all the oscillator functions stop. However, the contents of the CPU internal registers, on-chip RAM data, on-chip peripheral functions, and the states of the I/O ports are retained. This mode allows significant reduction in power consumption because the oscillator stops in this mode.
Clear the DTCST bit in DTCST of the DTC to 0 before executing the WAIT instruction.
When the WDT is used in watchdog timer mode or the IWDT is used, no transition to software standby mode is made. Stop the WDT before executing the WAIT instruction.
When the oscillation stop detection function is enabled*1, software standby mode cannot be entered. To make a transition to software standby mode, issue a WAIT instruction after disabling the oscillation stop detection function.
When software standby mode is in use, issue a WAIT instruction after making the following settings.

1. Clear the I bit*2 in PSW of the CPU to 0.
2. Set the interrupt destination to be used for recovery from software standby mode to the CPU.
3. Set the priority*3 of the interrupt to be used for recovery from software standby mode to a level higher than the setting of the IPL[3:0] bits*2 in PSW of the CPU.
4. Set the IENn bit*3 in IERm for the interrupt to be used for recovery from software standby mode to 1.
5. Execute a WAIT instruction (executing a WAIT instruction causes automatic setting of the I bit*2 in PSW of the CPU to 1).

Note 1. The oscillation stop detection function (the OSTDCR.OSTED bit) is valid after a reset is canceled.
Note 2. For details, see section 2, CPU.
Note 3. For details, see section 11, Interrupt Controller (ICU).

9.5.3.2 Canceling Software Standby Mode

Software standby mode is canceled by an external interrupt (NMI or IRQ0 to IRQ7), an internal interrupt (voltage monitoring), the reset signal from the RES# pin, a power-on reset, or a voltage monitoring reset.

1. Canceling by an interrupt
   When an interrupt request signal is input by an NMI, IRQ0 to IRQ7*1, or voltage monitoring, clock oscillation starts thus supplying stable clocks to the entire RX62T chip. After the time specified by the STS[4:0] bits in SBYCR has passed, software standby mode is canceled and the interrupt exception handling is started.
2. Canceling by the RES# pin
   When the RES# pin is driven low, clock oscillation starts and at the same time the clocks are supplied to the entire RX62T chip. Be sure to hold the RES# pin low until the clock oscillation settles. When the RES# pin is driven high, the CPU begins the reset exception handling.
3. Canceling by a power-on reset
   When a power-on reset is generated by a power-supply voltage drop, software standby mode is canceled.
4. Canceling by a voltage monitoring reset
   When a voltage monitoring reset is generated by a power-supply voltage drop, software standby mode is canceled and clock oscillation starts.

Note 1. For details, see section 11, Interrupt Controller (ICU).

9.5.3.3 Setting Oscillation Settling Time after Software Standby Mode is Canceled

Set the STS[4:0] bits in SBYCR as follows:

1. When using a crystal resonator
   Set the STS[4:0] bits so that the waiting time is no less than the oscillation settling time.
   Table 9.4 shows operating frequencies and waiting time corresponding to each setting of the STS[4:0] bits.
2. When using an external clock
   The PLL circuit settling time is necessary. Set the waiting time referring to Table 9.4.

Table 9.4 Oscillation Settling Time Setting

STS4	STS3	STS2	STS1	STS0	Waiting Time (States)	PCLK*1 (MHz) 50	25	8	Unit
0	0	0	0	0	Reserved	—	—	—	µs
				1	Reserved	—	—	—	
			1	0	Reserved	—	—	—	
				1	Reserved	—	—	—	
		1	0	0	Reserved	—	—	—	
				1	64	1.3	2.6	8.0	
			1	0	512	10.25	20.5	64.0	
				1	1024	20.5	41.0	128.0	
	1	0	0	0	2048	40.95	81.9	256.0	
				1	4096	0.08	0.16	0.51	ms
			1	0	16384	0.33	0.66	2.05	
				1	32768	0.655	1.31	4.10	
		1	0	0	65536	1.31	2.62	8.19	
				1	131072	2.62	5.24	16.38	
			1	0	262144	5.25	10.49	32.77	
				1	524288	10.49	20.97	65.54	
1	x	x	x	x	Reserved	—	—	—	

: Recommended time setting when an external clock is used

: Recommended time setting when a crystal resonator is used

Note 1. The PCLK is the output of the peripheral module frequency divider.
The oscillation settling time (including oscillator's unstable oscillation time) depends on the resonator characteristics.
The PCLK values in this table are reference values.

9.5.3.4 Example of Software Standby Mode Application

Figure 9.2 shows an example where a transition to software standby mode is made at the falling edge on the IRQ pin, and software standby mode is canceled at the rising edge on the IRQ pin.
In this example, an IRQ interrupt is accepted with the IRQMD[1:0] bits in IRQCRi of the ICU set to 01b (falling edge), and then the IRQMD[1:0] bits are set to 10b (rising edge). After that, the SSBY bit in SBYCR are set to 1, and then the WAIT instruction is executed. Thus a transition to software standby mode is made.
After that, software standby mode is canceled*1 at the rising edge on the IRQ pin.

Note 1. To return from software standby mode, settings of the interrupt controller (ICU) are also necessary. For details, see section 11, Interrupt Controller (ICU).

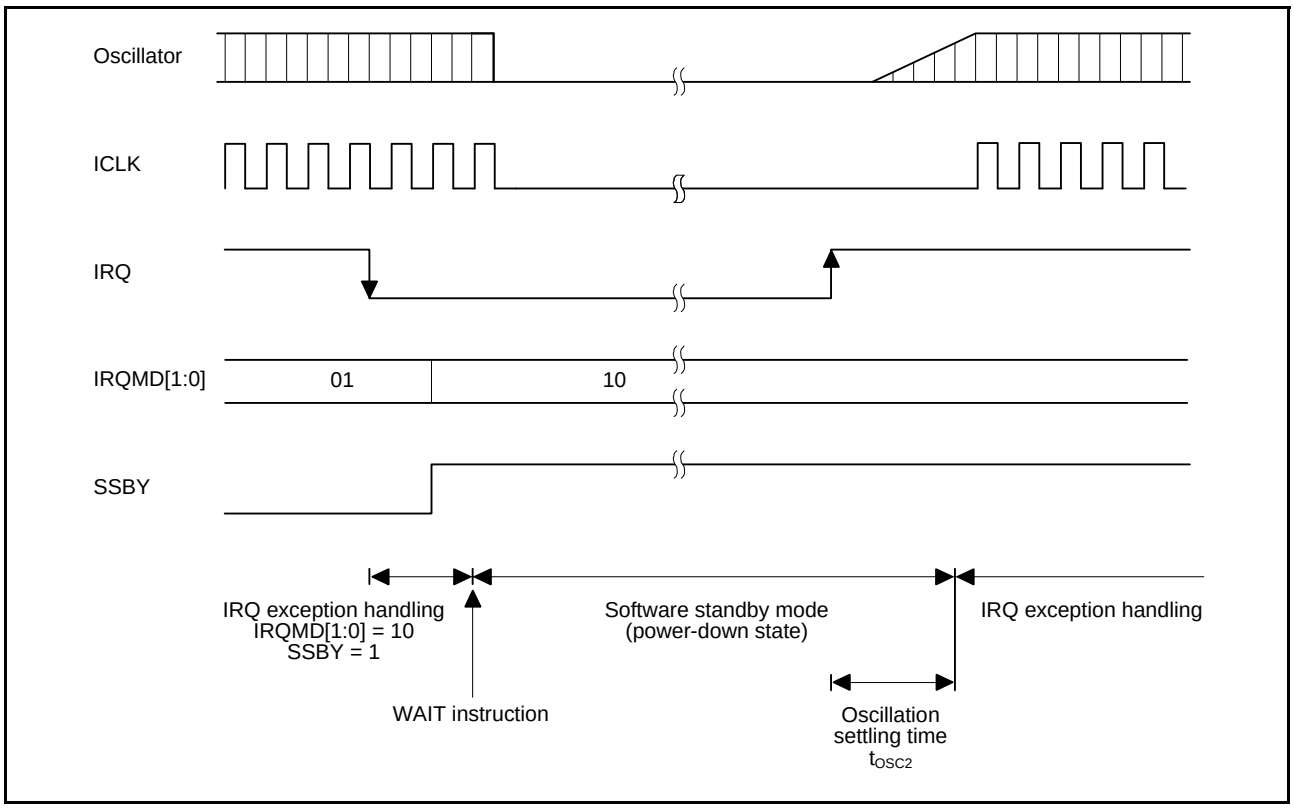


Figure 9.2 Example of Software Standby Mode Application

9.5.4 Deep Software Standby Mode

9.5.4.1 Transition to Deep Software Standby Mode

When the WAIT instruction is executed with the SSBY bit in SBYCR set to 1, a transition to software standby mode*1 is made. At this time, when the DPSBY bit in DPSBYCR is set to 1, a transition to deep software standby mode is made. However, if a software standby mode canceling source (NMI, IRQ0 to IRQ7 interrupt requests, or some internal interrupts of voltage monitoring) is generated concurrently when a transition to software standby mode is made, software standby mode is canceled regardless of the DPSBY setting, and the interrupt exception handling starts after the oscillation settling time for software standby mode specified by the STS[4:0] bits in SBYCR has passed.
When the SSBY and DPSBY bits are set to 1 and no software standby mode canceling source is generated, a transition to deep software standby mode is made immediately after transition to software standby mode.
In deep software standby mode, the CPU, on-chip peripheral function, on-chip RAM, and all the oscillator functions stop. Furthermore, the internal power supply to these modules stops, allowing significant reduction in power consumption. At this time, the contents of all the registers of the CPU and on-chip peripheral functions become undefined. All the on-chip RAM data also becomes undefined.
The voltage detection circuit and power-on reset circuit are enabled even in deep software standby mode.
The I/O port states remain unchanged from software standby mode.

Note 1. Conditions on the DTC, WDT, IWDT, and the oscillation stop detection function for transition to software standby mode should be met before the WAIT instruction is executed.

9.5.4.2 Canceling Deep Software Standby Mode

Deep software standby mode is canceled by an external interrupt (NMI, or IRQ0-A and IRQ1-A pins), an internal interrupt (voltage monitoring), the reset signal from the RES# pin, a power-on reset, or a voltage monitoring reset.

1. Canceling by an external or internal interrupt
   The DPSIFR holds the cancelation cause of deep software standby mode and the bits in this register are set to 1 when the corresponding cancelation requests are generated. When a bit is set to 1 and the corresponding cancelation cause is enabled in the DPSIER register, deep software standby mode is canceled.
   The DNMIF or DIRQnF flag in DPSIFR is set to 1 when an edge is generated on the NMI pin, or IRQ0-A and IRQ1-A pins enabled by the DNMIE bit in DPSIER or the DIRQnE bit (n = 1, 0) in DPSIER. Rising edge or falling edge is selectable with DPSIEGR for each pin.
   The DLVDIF flag is set to 1 when a voltage monitoring interrupt enabled by the DLDVIE bit in DPSIER is generated.
   When a deep software standby mode canceling source is generated, clock oscillation starts and the internal power supply begins at the same time, and then the internal reset signal is generated throughout the LSI. After the time specified by the WTSTS[5:0] bits in DPSWCR has passed, stable clocks are supplied to the entire LSI and the internal reset is released. At the same time, deep software standby mode is canceled and the reset exception handling starts.
   When deep software standby mode is canceled by an external or internal interrupt, the DPSRSTF flag in RSTSR is set to 1.
2. Canceling by the RES# pin
   When the RES# pin is driven low, clock oscillation starts and the internal power supply begins at the same time. Clocks are supplied to the LSI simultaneously with the start of clock oscillation. Be sure to hold the RES# pin low until the clock oscillation settles. When the RES# pin is driven high, the CPU begins the reset exception handling.
3. Canceling by a power-on reset
   When a power-on reset is generated by a power-supply voltage drop, deep software standby mode is canceled.
4. Canceling by a voltage monitoring reset
   When a voltage monitoring reset is generated by a power-supply voltage drop, deep software standby mode is canceled.

9.5.4.3 Pin States when Deep Software Standby Mode is Canceled

In deep software standby mode, I/O ports retain the same states from software standby mode. The inside of the LSI is initialized by an internal reset generated when deep software standby mode is canceled. Upon cancellation of deep software standby mode, the reset exception handling starts. The following shows the states of I/O ports at this time. Whether to initialize the I/O ports or to keep retaining the I/O port states at the time of software standby mode can be selected by the IOKEEP bit in DPSBYCR.

- When IOKEEP = 0

I/O ports are initialized by an internal reset generated when deep software standby mode is canceled.

- When IOKEEP = 1

Although the inside of the LSI is initialized by an internal reset generated when deep software standby mode is canceled, I/O ports keep retaining their states from software standby mode regardless of the LSI internal state. At this time, the I/O port states remain unchanged from software standby mode even if settings of I/O ports or peripheral modules are made. Then the retained I/O port states are released by clearing the IOKEEP bit to 0, and the LSI operates according to the internal state.

The IOKEEP bit is not initialized by an internal reset generated when deep software standby mode is canceled.

9.5.4.4 Setting Oscillation Settling Time after Deep Software Standby Mode is Canceled

1. Set the WTSTS[5:0] bits in DPSWCR as follows:
   When using a crystal resonator
2. Set the WTSTS[5:0] bits so that the waiting time is no less than the oscillation settling time.
   Table 9.5 shows EXTAL input clock frequencies and waiting time corresponding to each setting of the WTSTS[5:0] bits.
3. When using an external clock
   The PLL circuit settling time is necessary. Set the waiting time referring to Table 9.5.

Table 9.5 Oscillation Settling Time Setting

WTSTS 5	WTSTS 4	WTSTS 3	WTSTS 2	WTSTS 1	WTSTS 0	Waiting Time (States)	EXTAL Input Clock Frequency*1 (MHz) 12	10	8	Unit
0	0	0	0	0	0	Reserved	—	—	—	µs
					1	Reserved	—	—	—	
				1	0	Reserved	—	—	—	
					1	Reserved	—	—	—	
			1	0	0	Reserved	—	—	—	
					1	64	5.3	6.4	8.0	
				1	0	512	42.7	51.2	64.0	
					1	1024	85.3	102.4	128.0	
		1	0	0	0	2048	170.7	204.8	256.0	
					1	4096	0.34	0.41	0.51	ms
				1	0	16384	1.37	1.64	2.05	
					1	32768	2.73	3.26	4.10	
			1	0	0	65536	5.46	6.55	8.19	
					1	131072	10.92	13.11	16.38	
				1	0	262144	21.85	26.21	32.77	
					1	524288	43.69	52.43	65.54	
	1	×	×	×	×	Reserved	—	—	—	
1	×	×	×	×	×	Reserved	—	—	—	

: Recommended time setting when an external clock is used

: Recommended time setting when a crystal resonator is used

Note 1. The oscillation settling time (including oscillator's unstable oscillation time) depends on the resonator characteristics. The values of the EXTAL input clock frequency in this table are reference values.

9.5.4.5 Example of Deep Software Standby Mode Application

Figure 9.3 shows an example where a transition to deep software standby mode is made at the falling edge on the IRQ pin, and deep software standby mode is canceled at the rising edge on the IRQ pin.

In this example, an IRQ interrupt is accepted with the IRQMD[1:0] bits in IRQCRi of the ICU set to 01b (falling edge), and then the DIRQnEG bit (n = 1, 0) in DPSIEGR is set to 1 (rising edge). After that, the SSBY bit in SBYCR and the DPSBY bit in DPSBYCR are set to 1, and then the WAIT instruction is executed. Thus a transition to deep software standby mode is made.

After that, deep software standby mode is canceled at the rising edge on the IRQ pin.

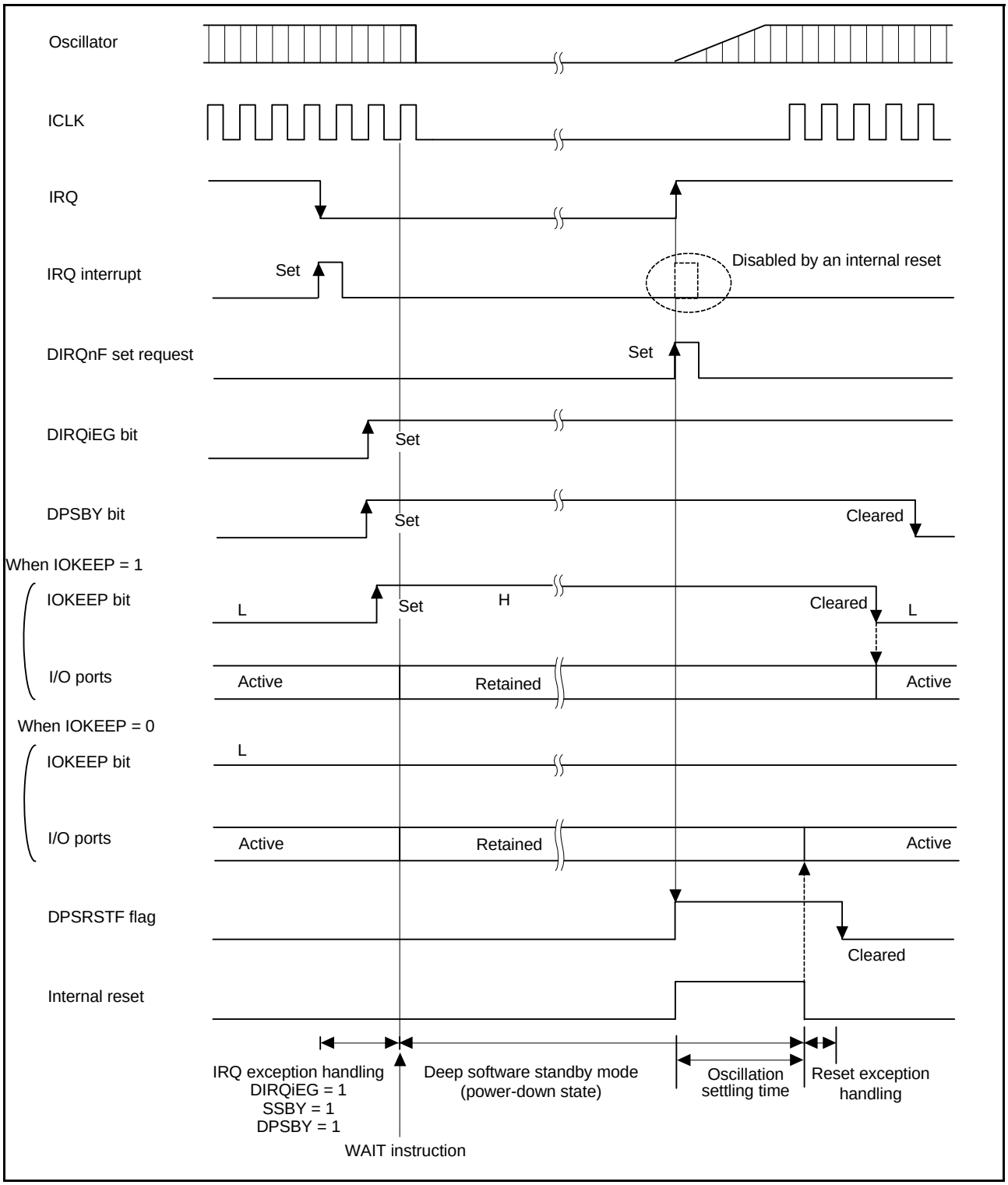


Figure 9.3 Example of Deep Software Standby Mode Application

9.5.4.6 Flowchart to Use Deep Software Standby Mode

Figure 9.4 shows an example of a flowchart to use deep software standby mode.
In this example, the DPSRSTF flag in RSTSR of the reset function is read after the reset exception handling to determine whether a reset was generated by the RES# pin or by the cancellation of deep software standby mode.
In the case of a reset by the RES# pin, a transition to deep software standby mode is made after required register settings.
In the case of a reset by the cancellation of deep software standby mode, the IOKEEP bit in DPSBYCR is cleared to 0 after the I/O port settings.

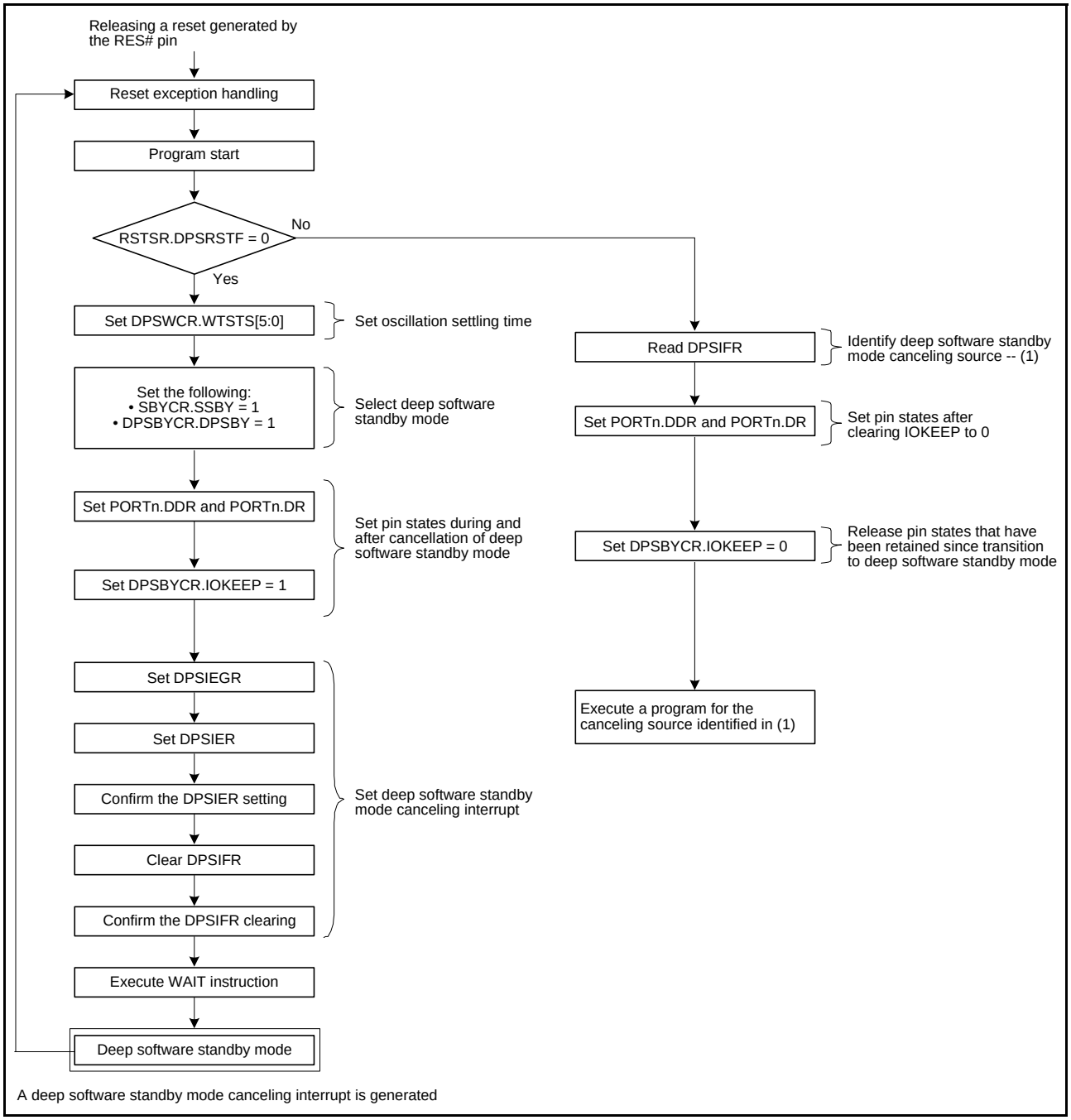


Figure 9.4 Example of Flowchart to Use Deep Software Standby Mode

9.6 Usage Notes

9.6.1 I/O Port States

I/O port states are retained in software standby mode and deep software standby mode. Therefore, supply current is not reduced while output signals are held high.

9.6.2 Module Stop State of the DTC

Before setting the MSTPA28 bit in MSTPCRA to 1, clear the DTCST bit in DTCST of the DTC to 0 so that initiating transfer by the DTC is not possible.
For details, see section 14, Data Transfer Controller (DTC).

9.6.3 On-Chip Peripheral Module Interrupts

Operation of relevant interrupt is disabled in the module stop state. Therefore, if the module stop state is made with an interrupt request pending, a CPU interrupt source or a DTC startup source cannot be cleared. For this reason, disable interrupts before entering the module stop state.

9.6.4 Write-Access to MSTPCRA, MSTPCRB, and MSTPCRC

Write-accesses to MSTPCRA, MSTPCRB, and MSTPCRC should be made only by the CPU.

9.6.5 Input Buffer Control by DIRQnE Bit (n = 1, 0)

When the input buffers for the P10/IRQ0-A and P11/IRQ1-A pins are enabled by setting the DIRQnE bit (n = 1, 0) in DPSIER to 1. Therefore, note that, although inputs to these pins are sent to the DIRQnF (n = 1, 0) bit in DPSIER, they are not sent to the interrupt controller, peripheral modules, and I/O ports. Use PORTn.ICR for inputs to the interrupt controller, peripheral modules, and I/O ports.

9.6.6 Conflict between Transition to Deep Software Standby Mode and Interrupt

If a conflict occurs between a transition to deep software standby mode and generation of a software standby mode canceling source, the transition to deep software standby mode is not realized but the software standby mode canceling sequence is started. After the oscillation settling time specified by the STS[4:0] bits in SBYCR for software standby mode has passed, the interrupt exception handling is started.
Note that if a conflict occurs between a transition to deep software standby mode and a request for release from software standby mode, an interrupt exception handling routine is required.

9.6.7 Timing of Wait Instructions

The WAIT instruction is executed before completion of the preceding register write; it may be executed before the register modification is reflected, causing unintended operation. To avoid this, always execute the WAIT instruction after confirming that the last write to the register has been completed.

10. Exceptions

10.1 Types of Exceptions

During the execution of a program by the CPU, the occurrence of certain events may necessitate suspending execution of the main flow of the program and starting the execution of another flow. Such events are called exceptions.
The RX CPU supports the seven types of exceptions listed in Figure 10.1.
The occurrence of an exception causes the processor mode to switch to supervisor mode.

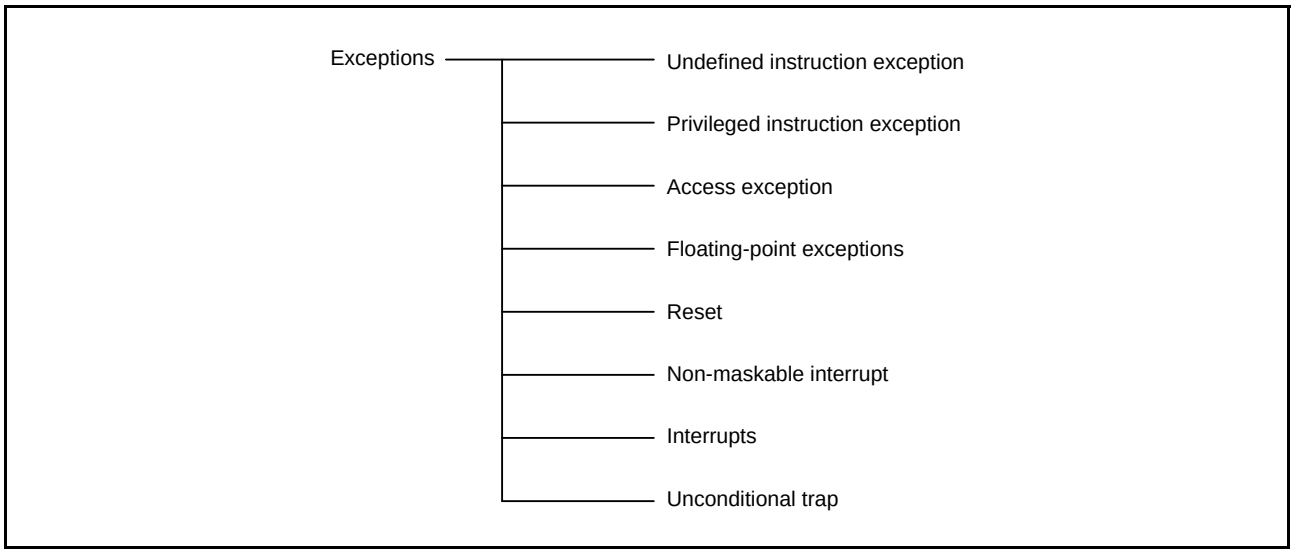


Figure 10.1 Types of Exception

10.1.1 Undefined Instruction Exception

An undefined instruction exception occurs when execution of an undefined instruction (an instruction not implemented) is detected.

10.1.2 Privileged Instruction Exception

A privileged instruction exception occurs when execution of a privileged instruction is detected while operation is in user mode. Privileged instructions can only be executed in supervisor mode.

10.1.3 Access Exception

An access exception occurs when an error in the form of access to memory by the CPU is detected. When the error detected by the memory protection unit is an execution memory protection error, an instruction access exception occurs. When the error is a data memory protection error, an operand access exception occurs.

10.1.4 Floating-Point Exceptions

Floating-point exceptions are generated on the detection of any of five events specified in the IEEE754 standard, namely overflow, underflow, inexact, division-by-zero, and invalid operation. The exception processing of floating-point exceptions is masked when the EX, EU, EZ, EO, or EV bit in FPSW is 0.

10.1.5 Reset

A reset through input of the reset signal to the CPU causes the exception request. This has the highest priority of any exception and is always accepted.

10.1.6 Non-Maskable Interrupt

The non-maskable interrupt is generated by input of the non-maskable interrupt signal to the CPU and is only used when a fatal fault is considered to have occurred in the system. Never end the exception handling routine for the non-maskable interrupt with an attempt to return to the program that was being executed at the time of interrupt generation.

10.1.7 Interrupts

Interrupts are generated by the input of interrupt signals to the CPU. A fast interrupt can be selected as the interrupt with the highest priority. In the case of the fast interrupt, hardware pre-processing and hardware post-processing are handled fast. The priority level of the fast interrupt is fifteen (the highest). The exception handling of interrupts is masked when the I bit in PSW is 0.

10.1.8 Unconditional Trap

An unconditional trap is generated when the INT or BRK instruction is executed.

10.2 Exception Handling Procedure

For exception handling, part of the processing is handled automatically by hardware and part is handled by a program (the exception handling routine) that has been written by the user. Figure 10.2 shows the handling procedure when an exception other than a reset is accepted.

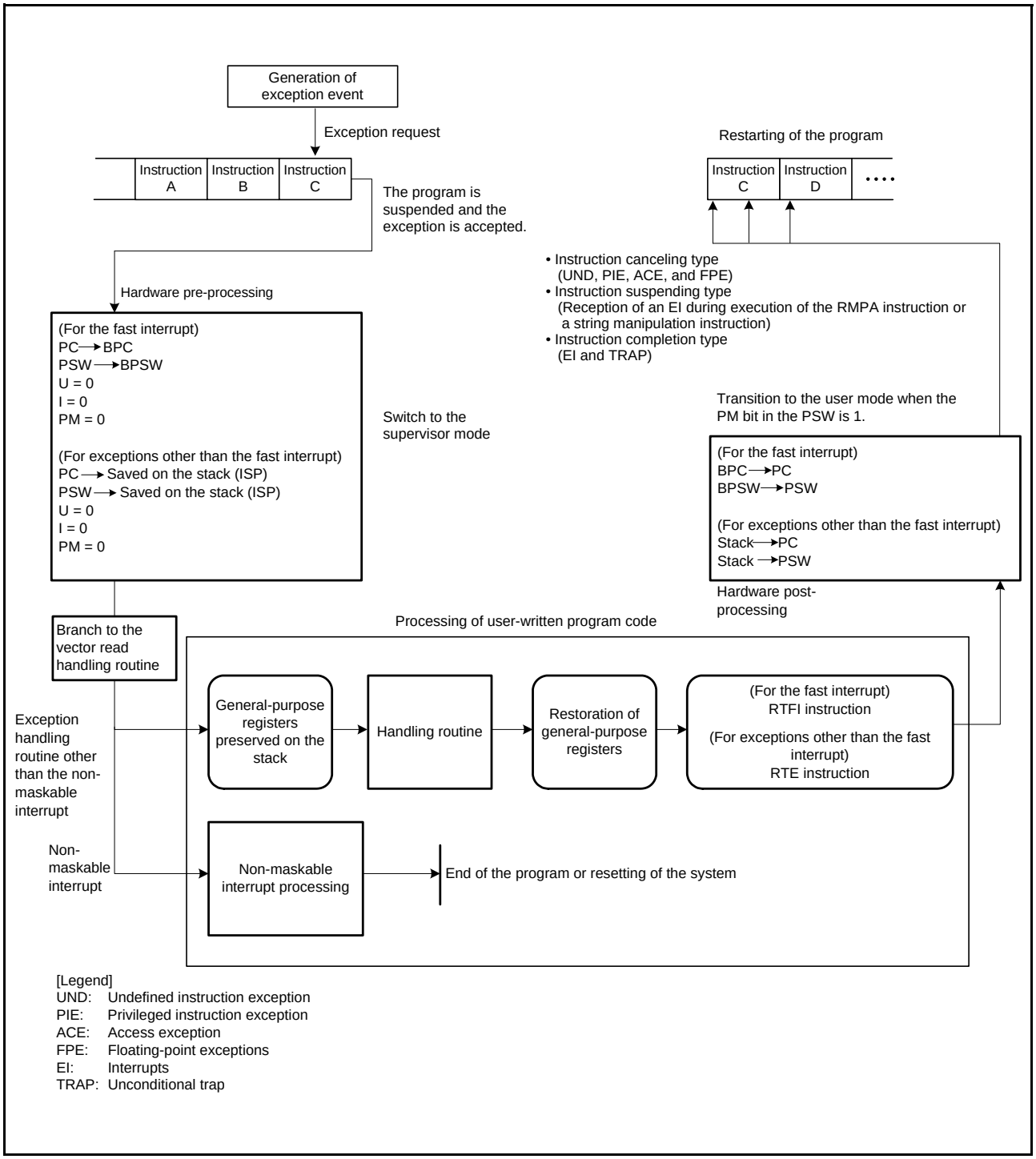


Figure 10.2 Outline of the Exception Handling Procedure

When an exception is accepted, hardware processing by the RX CPU is followed by vector access to acquire the address of the branch destination. A vector address is allocated to each exception. The branch destination address of the exception handling routine for the given exception is written to each vector address. The combination is referred to as a vector.

Hardware pre-processing by the RX CPU handles saving of the contents of the program counter (PC) and processor status word (PSW). In the case of the fast interrupt, the contents are saved in the backup program counter (BPC) and the backup processor status word (BPSW), respectively. In the case of other exceptions, the contents are preserved in the stack area.

General purpose registers and control registers other than the PC and PSW that are to be used within the exception handling routine must be preserved on the stack by user program code at the start of the exception handling routine.

On completion of processing by exception handling routine, registers preserved under program control are restored and the RTE instruction is executed to restore execution from the exception handling routine to the original program. For return from the fast interrupt, the RTFI instruction is used instead. In the case of the non-maskable interrupt, however, end the program or reset the system without returning to the original program.

Hardware post-processing by the RX CPU handles restoration of the pre-exception contents of the PC and PSW. In the case of the fast interrupt, the contents of the BPC and BPSW are restored to the PC and PSW, respectively. In the case of other exceptions, the contents are restored from the stack area to the PC and PSW.

10.3 Acceptance of Exceptions

When an exception occurs, the CPU suspends the execution of the program and processing branches to the start of the exception handling routine

10.3.1 Timing of Acceptance and Saved PC Values

Table 10.1 lists the timing of acceptance and program counter (PC) value to be saved for each type of exception event.

Table 10.1 Timing of Acceptance and Saved PC Value

Exception		Type of Handling	Timing of Acceptance	Value Saved in the BPC/ on the Stack
Undefined instruction exception		Instruction canceling type	During instruction execution	PC value of the instruction that generated the exception
Privileged instruction exception		Instruction canceling type	During instruction execution	PC value of the instruction that generated the exception
Access exception		Instruction canceling type	During instruction execution	PC value of the instruction that generated the exception
Floating-point exceptions		Instruction canceling type	During instruction execution	PC value of the instruction that generated the exception
Reset		Program abandonment type	At each cycle	None
Non-maskable interrupt	During execution of the RMPA, SCMPU, SMOVB, SMOVF, SMOVU, SSTR, SUNTIL, and SWHILE instructions	Instruction suspending type	During instruction execution	PC value of the instruction being executed
	Other than the above	Instruction completion type	At the next break between instructions	PC value of the next instruction
Interrupts	During execution of the RMPA, SCMPU, SMOVB, SMOVF, SMOVU, SSTR, SUNTIL, and SWHILE instructions	Instruction suspending type	During instruction execution	PC value of the instruction being executed
	Other than the above	Instruction completion type	At the next break between instructions	PC value of the next instruction
Unconditional trap		Instruction completion type	At the next break between instructions	PC value of the next instruction

10.3.2 Vector and Site for Saving the Values in the PC and PSW

The vector for each type of exception and the site for saving the values of the program counter (PC) and processor status word (PSW) are listed in Table 10.2.

Table 10.2 Vector and Site for Saving the Values in the PC and PSW

Exception		Vector	Site for Saving the Values in the PC and PSW
Undefined instruction exception		Fixed vector table	Stack
Privileged instruction exception		Fixed vector table	Stack
Access exception		Fixed vector table	Stack
Floating-point exceptions		Fixed vector table	Stack
Reset		Fixed vector table	Nowhere
Non-maskable interrupt		Fixed vector table	Stack
Interrupts	Fast interrupt	FINTV	BPC and BPSW
	Other than the above	Relocatable vector table (INTB)	Stack
Unconditional trap		Relocatable vector table (INTB)	Stack

10.4 Hardware Processing for Accepting and Returning from Exceptions

This section describes the hardware processing for accepting and returning from exceptions other than a reset.

(1) Hardware pre-processing for accepting an exception

(a) Saving the values in the PSW

- For the fast interrupt
  PSW → BPSW
- For other exceptions
  PSW → Stack area

Note: • The values in the FPSW are not saved by hardware pre-processing. Therefore, if floating-point instructions are to be used within an exception handling routine, the user must ensure that these values are saved on the stack.

(b) Updating of the PM, U, and I bits in the PSW

I: Cleared
U: Cleared
PM: Cleared

(c) Saving the values in the PC

- For the fast interrupt
  PC → BPC
- For other exceptions
  PC → Stack area

(d) Set the branch-destination address of the exception handling routine in the PC

Processing is shifted to the exception handling routine by acquiring the vector corresponding to the exception and branching accordingly.

(2) Hardware post-processing for execution of RTE and RTFI instructions

(a) Restoring the values in the PSW

- For the fast interrupt
  BPSW → PSW
- For other exceptions
  Stack area→ PSW

(b) Restoring the values in the PC

- For the fast interrupt
  BPC → PC
- For other exceptions
  Stack area→ PC

10.5 Hardware Pre-Processing

The sequences of hardware pre-processing from reception of each exception request to execution of the associated exception processing routine are explained below.

10.5.1 Undefined Instruction Exception

1. The value of the processor status word (PSW) is saved on the stack (ISP).
2. The processor mode select bit (PM), the stack pointer select bit (U), and the interrupt enable bit (I) in the PSW are cleared to 0.
3. The value of the program counter (PC) is saved on the stack (ISP).
4. The address of the processing routine is fetched from the vector address, FFFFFFDCh.
5. The PC is set to the fetched address and processing branches to the start of the exception handling routine.

10.5.2 Privileged Instruction Exception

1. The value in the processor status word (PSW) is saved on the stack (ISP).
2. The processor mode select bit (PM), the stack pointer select bit (U), and the interrupt enable bit (I) in the PSW are cleared to 0.
3. The value of the program counter (PC) is saved on the stack (ISP).
4. The address of the processing routine is fetched from the vector address, FFFFFFD0h.
5. The PC is set to the fetched address and processing branches to the start of the exception handling routine.

10.5.3 Access Exception

1. The value of the processor status word (PSW) is saved on the stack (ISP).
2. The processor mode select bit (PM), the stack pointer select bit (U), and the interrupt enable bit (I) in the PSW are cleared to 0.
3. The value of the program counter (PC) is saved on the stack (ISP).
4. The address of the processing routine is fetched from the vector address, FFFFFFD4h.
5. The PC is set to the fetched address and processing branches to the start of the exception handling routine.

10.5.4 Floating-Point Exceptions

1. The value in the processor status word (PSW) is saved on the stack (ISP).
2. The processor mode select bit (PM), the stack pointer select bit (U), and the interrupt enable bit (I) in the PSW are cleared to 0.
3. The value of the program counter (PC) is saved on the stack (ISP).
4. The address of the processing routine is fetched from the vector address, FFFFFFE4h.
5. The PC is set to the fetched address and processing branches to the start of the exception handling routine.

10.5.5 Reset

1. The control registers are initialized.
2. The address of the processing routine is fetched from the vector address, FFFFFFFCh.
3. The PC is set to the fetched address.

10.5.6 Non-Maskable Interrupt

1. The value of the processor status word (PSW) is saved on the stack (ISP).
2. The processor mode select bit (PM), the stack pointer select bit (U), and the interrupt enable bit (I) in the PSW are cleared to 0.
3. If the interrupt was generated during the execution of an RMPA, SCMPU, SMOVB, SMOVF, SMOVU, SSTR, SUNTIL, or SWHILE instruction, the value of the program counter (PC) for that instruction is saved on the stack (ISP). For other instructions, the PC value of the next instruction is saved.
4. The processor interrupt priority level bits (IPL[3:0]) in the PSW are set to "Fh".
5. The address of the processing routine is fetched from the vector address, FFFFFFF8h.
6. The PC is set to the fetched address and the processing branches to the start of the exception handling routine.

10.5.7 Interrupts

1. The value of the processor status word (PSW) is saved on the stack (ISP) or, for the fast interrupt, in the backup processor status word (BPSW).
2. The processor mode select bit (PM), the stack pointer select bit (U), and the interrupt enable bit (I) in the PSW are cleared to 0.
3. If the interrupt was generated during the execution of an RMPA, SCMPU, SMOVB, SMOVF, SMOVU, SSTR, SUNTIL, or SWHILE instruction, the value of the program counter (PC) for that instruction is saved. For other instructions, the PC value of the next instruction is saved. Saving of the PC is in the backup program counter (BPC) for fast interrupts.
4. The processor interrupt priority level bits (IPL[3:0]) in the PSW indicate the interrupt priority level of the interrupt.
5. The address of the processing routine for an interrupt source other than the fast interrupt is fetched from the relocatable vector table. For the fast interrupt, the address is fetched from the fast interrupt vector register (FINTV).
6. The PC is set to the fetched address and processing branches to the start of the exception handling routine.

10.5.8 Unconditional Trap

1. The value in the processor status word (PSW) is saved on the stack (ISP).
2. The processor mode select bit (PM), the stack pointer select bit (U), and the interrupt enable bit (I) in the PSW are cleared to 0.
3. The value of the program counter (PC) for the next instruction is saved on the stack (ISP).
4. For the INT instruction, the value at the vector corresponding to the INT instruction number is fetched from the relocatable vector table.
   For the BRK instruction, the value at the vector from the start address is fetched from the relocatable vector table.
5. The PC is set to the fetched address and the processing branches to the start of the exception handling routine.

10.6 Return from Exception Processing Routines

Executing the instructions listed in Table 10.3 at the end of the corresponding exception processing routines restores the values of the program counter (PC) and processor status word (PSW) that were saved on the stack or in the control registers (BPC and BPSW) immediately before the exception processing sequence.

Table 10.3 Return from Exception Processing Routines

Exception		Instruction for Return
Undefined instruction exception		RTE
Privileged instruction exception		RTE
Access exception		RTE
Floating-point exceptions		RTE
Reset		Return is impossible
Non-maskable interrupt		Return is impossible
Interrupts	Fast interrupt	RTFI
	Other than the above	RTE
Unconditional trap		RTE

Order of Priority for Exceptions

The order of priority for exceptions is given in Table 10.4. When multiple exceptions are generated at the same time, the exception with the highest priority is accepted first.

Table 10.4 Order of Priority for Exceptions

Order of Priority		Exception
High	1	Reset
↑	2	Non-maskable interrupt
	3	Interrupts
	4	Instruction access exception
	5	Undefined instruction exception Privileged instruction exception
	6	Unconditional trap
	7	Operand access exception
Low	8	Floating-point exceptions

11. Interrupt Controller (ICU)

11.1 Overview

The interrupt controller (ICU) receives interrupt signals from the peripheral modules and external pins, sends interrupts to the CPU, and activates the DTC.

Table 11.1 lists the specifications of the interrupt controller, and Figure 11.1 shows a block diagram of the interrupt controller.

Table 11.1 Specifications of the Interrupt Controller

Item		Description
Interrupts	Peripheral function interrupts	• Interrupts from peripheral modules • Number of sources: 101 • Interrupt detection: Edge detection/level detection • Edge detection or level detection is determined for each source of connected peripheral modules.
	External pin interrupts	• Interrupts from pins IRQ7 to IRQ0 • Number of sources: 8 • Interrupt detection: Low level/falling edge/rising edge/rising and falling edges • One of these detection methods can be set for each source.
	Software interrupt	• Interrupt generated by writing to a register • One interrupt source
	Interrupt priority	Specified by registers.
	Fast interrupt function	Faster interrupt processing of the CPU can be set only for a single interrupt source.
	DTC control	• The DTC can be activated by interrupt sources. • Number of DTC activating sources: 87 (78 peripheral function interrupts + 8 external pin interrupts + 1 software interrupt)
Non-maskable interrupts	NMI pin interrupts	• Interrupt from the NMI pin • Interrupt detection: Falling edge/rising edge
	Voltage monitoring interrupt	Interrupt during power-voltage fall detection
	Oscillation stop detection interrupt	Interrupt during oscillation stop detection
Return from power-down modes		• Sleep mode: Return is initiated by non-maskable interrupts or any other interrupt source. • All-module clock stop mode: Return is initiated by non-maskable interrupts, IRQ7 to IRQ0 interrupts, and WDT interrupts. • Software standby mode: Return is initiated by non-maskable interrupts and IRQ7 to IRQ0 interrupts.

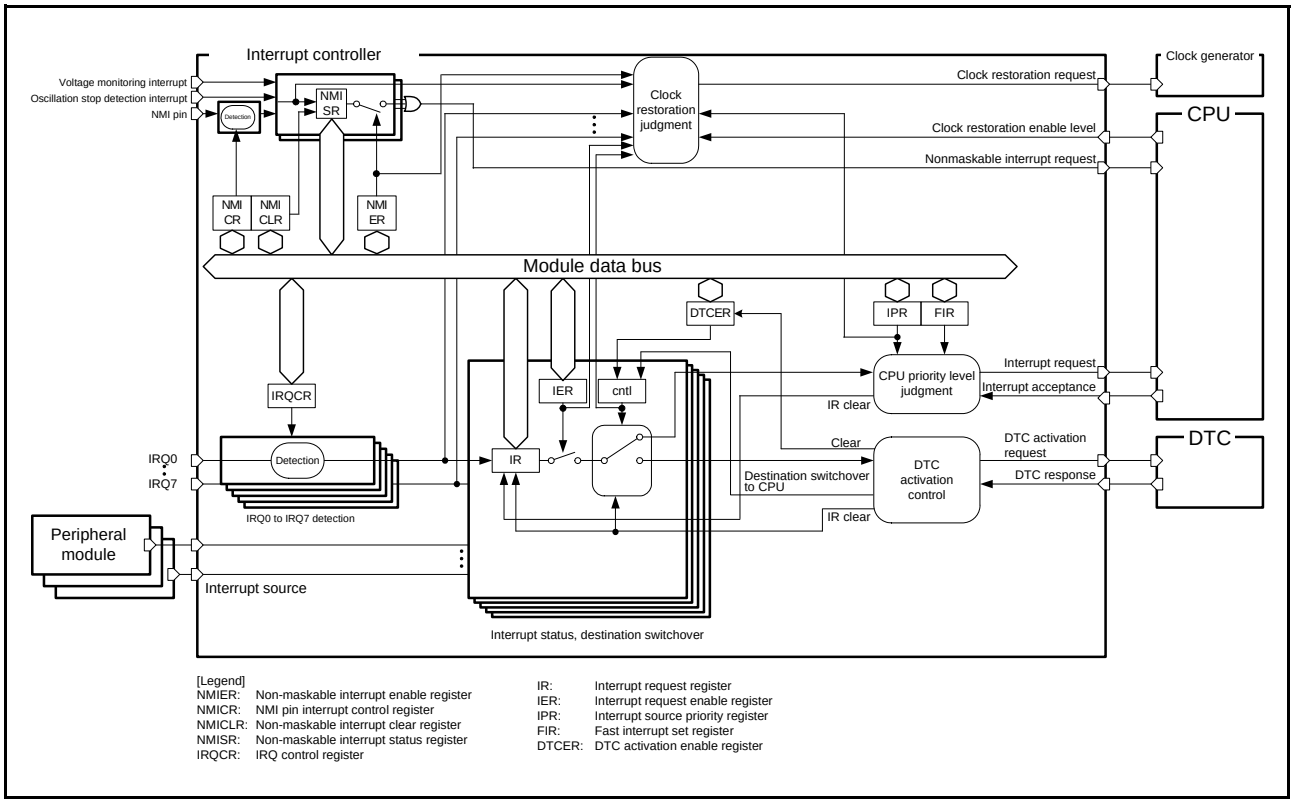


Figure 11.1 Block Diagram of Interrupt Controller

Table 11.2 shows the input/output pins of the interrupt controller.

Table 11.2 Pin Configuration of ICU

Pin Name	I/O	Description
NMI	Input	Non-maskable interrupt request pin
IRQ7 to IRQ0	Input	External interrupt request pins

11.2 Register Descriptions

Table 11.3 lists the registers of the interrupt controller.

Table 11.3 Registers of the Interrupt Controller (1 / 7)

Register Name	Symbol	Value after Reset	Address	Access Size
Interrupt source register 016	IR016	00h	0008 7010h	8
Interrupt source register 021	IR021	00h	0008 7015h	8
Interrupt source register 023	IR023	00h	0008 7017h	8
Interrupt source register 027	IR027	00h	0008 701Bh	8
Interrupt source register 028	IR028	00h	0008 701Ch	8
Interrupt source register 029	IR029	00h	0008 701Dh	8
Interrupt source register 030	IR030	00h	0008 701Eh	8
Interrupt source register 031	IR031	00h	0008 701Fh	8
Interrupt source register 044	IR044	00h	0008 702Ch	8
Interrupt source register 045	IR045	00h	0008 702Dh	8
Interrupt source register 046	IR046	00h	0008 702Eh	8
Interrupt source register 047	IR047	00h	0008 702Fh	8
Interrupt source register 056	IR056	00h	0008 7038h	8
Interrupt source register 057	IR057	00h	0008 7039h	8
Interrupt source register 058	IR058	00h	0008 703Ah	8
Interrupt source register 059	IR059	00h	0008 703Bh	8
Interrupt source register 060	IR060	00h	0008 703Ch	8
Interrupt source register 064	IR064	00h	0008 7040h	8
Interrupt source register 065	IR065	00h	0008 7041h	8
Interrupt source register 066	IR066	00h	0008 7042h	8
Interrupt source register 067	IR067	00h	0008 7043h	8
Interrupt source register 068	IR068	00h	0008 7044h	8
Interrupt source register 069	IR069	00h	0008 7045h	8
Interrupt source register 070	IR070	00h	0008 7046h	8
Interrupt source register 071	IR071	00h	0008 7047h	8
Interrupt source register 096	IR096	00h	0008 7060h	8
Interrupt source register 098	IR098	00h	0008 7062h	8
Interrupt source register 102	IR102	00h	0008 7066h	8
Interrupt source register 103	IR103	00h	0008 7067h	8
Interrupt source register 106	IR106	00h	0008 706Ah	8
Interrupt source register 114	IR114	00h	0008 7072h	8
Interrupt source register 115	IR115	00h	0008 7073h	8
Interrupt source register 116	IR116	00h	0008 7074h	8
Interrupt source register 117	IR117	00h	0008 7075h	8
Interrupt source register 118	IR118	00h	0008 7076h	8
Interrupt source register 119	IR119	00h	0008 7077h	8
Interrupt source register 120	IR120	00h	0008 7078h	8
Interrupt source register 121	IR121	00h	0008 7079h	8
Interrupt source register 122	IR122	00h	0008 707Ah	8
Interrupt source register 123	IR123	00h	0008 707Bh	8
Interrupt source register 124	IR124	00h	0008 707Ch	8
Interrupt source register 125	IR125	00h	0008 707Dh	8

Table 11.3 Registers of the Interrupt Controller (2 / 7)

Register Name	Symbol	Value after Reset	Address	Access Size
Interrupt source register 126	IR126	00h	0008 707Eh	8
Interrupt source register 127	IR127	00h	0008 707Fh	8
Interrupt source register 128	IR128	00h	0008 7080h	8
Interrupt source register 129	IR129	00h	0008 7081h	8
Interrupt source register 130	IR130	00h	0008 7082h	8
Interrupt source register 131	IR131	00h	0008 7083h	8
Interrupt source register 132	IR132	00h	0008 7084h	8
Interrupt source register 133	IR133	00h	0008 7085h	8
Interrupt source register 134	IR134	00h	0008 7086h	8
Interrupt source register 135	IR135	00h	0008 7087h	8
Interrupt source register 136	IR136	00h	0008 7088h	8
Interrupt source register 137	IR137	00h	0008 7089h	8
Interrupt source register 138	IR138	00h	0008 708Ah	8
Interrupt source register 139	IR139	00h	0008 708Bh	8
Interrupt source register 140	IR140	00h	0008 708Ch	8
Interrupt source register 141	IR141	00h	0008 708Dh	8
Interrupt source register 142	IR142	00h	0008 708Eh	8
Interrupt source register 143	IR143	00h	0008 708Fh	8
Interrupt source register 144	IR144	00h	0008 7090h	8
Interrupt source register 145	IR145	00h	0008 7091h	8
Interrupt source register 146	IR146	00h	0008 7092h	8
Interrupt source register 149	IR149	00h	0008 7095h	8
Interrupt source register 150	IR150	00h	0008 7096h	8
Interrupt source register 151	IR151	00h	0008 7097h	8
Interrupt source register 152	IR152	00h	0008 7098h	8
Interrupt source register 153	IR153	00h	0008 7099h	8
Interrupt source register 170	IR170	00h	0008 70AAh	8
Interrupt source register 171	IR171	00h	0008 70ABh	8
Interrupt source register 172	IR172	00h	0008 70ACh	8
Interrupt source register 173	IR173	00h	0008 70ADh	8
Interrupt source register 174	IR174	00h	0008 70AEh	8
Interrupt source register 175	IR175	00h	0008 70AFh	8
Interrupt source register 176	IR176	00h	0008 70B0h	8
Interrupt source register 177	IR177	00h	0008 70B1h	8
Interrupt source register 178	IR178	00h	0008 70B2h	8
Interrupt source register 179	IR179	00h	0008 70B3h	8
Interrupt source register 180	IR180	00h	0008 70B4h	8
Interrupt source register 181	IR181	00h	0008 70B5h	8
Interrupt source register 182	IR182	00h	0008 70B6h	8
Interrupt source register 183	IR183	00h	0008 70B7h	8
Interrupt source register 184	IR184	00h	0008 70B8h	8
Interrupt source register 186	IR186	00h	0008 70BAh	8
Interrupt source register 187	IR187	00h	0008 70BBh	8
Interrupt source register 188	IR188	00h	0008 70BCh	8
Interrupt source register 189	IR189	00h	0008 70BDh	8

Table 11.3 Registers of the Interrupt Controller (3 / 7)

Register Name	Symbol	Value after Reset	Address	Access Size
Interrupt source register 190	IR190	00h	0008 70BEh	8
Interrupt source register 192	IR192	00h	0008 70C0h	8
Interrupt source register 193	IR193	00h	0008 70C1h	8
Interrupt source register 194	IR194	00h	0008 70C2h	8
Interrupt source register 195	IR195	00h	0008 70C3h	8
Interrupt source register 196	IR196	00h	0008 70C4h	8
Interrupt source register 214	IR214	00h	0008 70D6h	8
Interrupt source register 215	IR215	00h	0008 70D7h	8
Interrupt source register 216	IR216	00h	0008 70D8h	8
Interrupt source register 217	IR217	00h	0008 70D9h	8
Interrupt source register 218	IR218	00h	0008 70DAh	8
Interrupt source register 219	IR219	00h	0008 70DBh	8
Interrupt source register 220	IR220	00h	0008 70DCh	8
Interrupt source register 221	IR221	00h	0008 70DDh	8
Interrupt source register 222	IR222	00h	0008 70DEh	8
Interrupt source register 223	IR223	00h	0008 70DFh	8
Interrupt source register 224	IR224	00h	0008 70E0h	8
Interrupt source register 225	IR225	00h	0008 70E1h	8
Interrupt source register 246	IR246	00h	0008 70F6h	8
Interrupt source register 247	IR247	00h	0008 70F7h	8
Interrupt source register 248	IR248	00h	0008 70F8h	8
Interrupt source register 249	IR249	00h	0008 70F9h	8
Interrupt source register 254	IR254	00h	0008 70FEh	8
DTC activation enable register 027	DTCER027	00h	0008 711Bh	8
DTC activation enable register 028	DTCER028	00h	0008 711Ch	8
DTC activation enable register 029	DTCER029	00h	0008 711Dh	8
DTC activation enable register 030	DTCER030	00h	0008 711Eh	8
DTC activation enable register 031	DTCER031	00h	0008 711Fh	8
DTC activation enable register 045	DTCER045	00h	0008 712Dh	8
DTC activation enable register 046	DTCER046	00h	0008 712Eh	8
DTC activation enable register 064	DTCER064	00h	0008 7140h	8
DTC activation enable register 065	DTCER065	00h	0008 7141h	8
DTC activation enable register 066	DTCER066	00h	0008 7142h	8
DTC activation enable register 067	DTCER067	00h	0008 7143h	8
DTC activation enable register 068	DTCER068	00h	0008 7144h	8
DTC activation enable register 069	DTCER069	00h	0008 7145h	8
DTC activation enable register 070	DTCER070	00h	0008 7146h	8
DTC activation enable register 071	DTCER071	00h	0008 7147h	8
DTC activation enable register 098	DTCER098	00h	0008 7162h	8
DTC activation enable register 102	DTCER102	00h	0008 7166h	8
DTC activation enable register 103	DTCER103	00h	0008 7167h	8
DTC activation enable register 106	DTCER106	00h	0008 716Ah	8
DTC activation enable register 114	DTCER114	00h	0008 7172h	8
DTC activation enable register 115	DTCER115	00h	0008 7173h	8
DTC activation enable register 116	DTCER116	00h	0008 7174h	8

Table 11.3 Registers of the Interrupt Controller (4 / 7)

Register Name	Symbol	Value after Reset	Address	Access Size
DTC activation enable register 117	DTCER117	00h	0008 7175h	8
DTC activation enable register 121	DTCER121	00h	0008 7179h	8
DTC activation enable register 122	DTCER122	00h	0008 717Ah	8
DTC activation enable register 125	DTCER125	00h	0008 717Dh	8
DTC activation enable register 126	DTCER126	00h	0008 717Eh	8
DTC activation enable register 129	DTCER129	00h	0008 7181h	8
DTC activation enable register 130	DTCER130	00h	0008 7182h	8
DTC activation enable register 131	DTCER131	00h	0008 7183h	8
DTC activation enable register 132	DTCER132	00h	0008 7184h	8
DTC activation enable register 134	DTCER134	00h	0008 7186h	8
DTC activation enable register 135	DTCER135	00h	0008 7187h	8
DTC activation enable register 136	DTCER136	00h	0008 7188h	8
DTC activation enable register 137	DTCER137	00h	0008 7189h	8
DTC activation enable register 138	DTCER138	00h	0008 718Ah	8
DTC activation enable register 139	DTCER139	00h	0008 718Bh	8
DTC activation enable register 140	DTCER140	00h	0008 718Ch	8
DTC activation enable register 141	DTCER141	00h	0008 718Dh	8
DTC activation enable register 142	DTCER142	00h	0008 718Eh	8
DTC activation enable register 143	DTCER143	00h	0008 718Fh	8
DTC activation enable register 144	DTCER144	00h	0008 7190h	8
DTC activation enable register 145	DTCER145	00h	0008 7191h	8
DTC activation enable register 149	DTCER149	00h	0008 7195h	8
DTC activation enable register 150	DTCER150	00h	0008 7196h	8
DTC activation enable register 151	DTCER151	00h	0008 7197h	8
DTC activation enable register 152	DTCER152	00h	0008 7198h	8
DTC activation enable register 153	DTCER153	00h	0008 7199h	8
DTC activation enable register 174	DTCER174	00h	0008 71AEh	8
DTC activation enable register 175	DTCER175	00h	0008 71AFh	8
DTC activation enable register 176	DTCER176	00h	0008 71B0h	8
DTC activation enable register 177	DTCER177	00h	0008 71B1h	8
DTC activation enable register 178	DTCER178	00h	0008 71B2h	8
DTC activation enable register 179	DTCER179	00h	0008 71B3h	8
DTC activation enable register 180	DTCER180	00h	0008 71B4h	8
DTC activation enable register 181	DTCER181	00h	0008 71B5h	8
DTC activation enable register 182	DTCER182	00h	0008 71B6h	8
DTC activation enable register 183	DTCER183	00h	0008 71B7h	8
DTC activation enable register 184	DTCER184	00h	0008 71B8h	8
DTC activation enable register 186	DTCER186	00h	0008 71BAh	8
DTC activation enable register 187	DTCER187	00h	0008 71BBh	8
DTC activation enable register 188	DTCER188	00h	0008 71BCh	8
DTC activation enable register 189	DTCER189	00h	0008 71BDh	8
DTC activation enable register 190	DTCER190	00h	0008 71BEh	8
DTC activation enable register 192	DTCER192	00h	0008 71C0h	8
DTC activation enable register 193	DTCER193	00h	0008 71C1h	8
DTC activation enable register 194	DTCER194	00h	0008 71C2h	8

Table 11.3 Registers of the Interrupt Controller (5 / 7)

Register Name	Symbol	Value after Reset	Address	Access Size
DTC activation enable register 195	DTCER195	00h	0008 71C3h	8
DTC activation enable register 196	DTCER196	00h	0008 71C4h	8
DTC activation enable register 215	DTCER215	00h	0008 71D7h	8
DTC activation enable register 216	DTCER216	00h	0008 71D8h	8
DTC activation enable register 219	DTCER219	00h	0008 71DBh	8
DTC activation enable register 220	DTCER220	00h	0008 71DCh	8
DTC activation enable register 223	DTCER223	00h	0008 71DFh	8
DTC activation enable register 224	DTCER224	00h	0008 71E0h	8
DTC activation enable register 247	DTCER247	00h	0008 71F7h	8
DTC activation enable register 248	DTCER248	00h	0008 71F8h	8
DTC activation enable register 254	DTCER254	00h	0008 71FEh	8
Interrupt request enable register 02	IER02	00h	0008 7202h	8
Interrupt request enable register 03	IER03	00h	0008 7203h	8
Interrupt request enable register 05	IER05	00h	0008 7205h	8
Interrupt request enable register 07	IER07	00h	0008 7207h	8
Interrupt request enable register 08	IER08	00h	0008 7208h	8
Interrupt request enable register 0C	IER0C	00h	0008 720Ch	8
Interrupt request enable register 0D	IER0D	00h	0008 720Dh	8
Interrupt request enable register 0E	IER0E	00h	0008 720Eh	8
Interrupt request enable register 0F	IER0F	00h	0008 720Fh	8
Interrupt request enable register 10	IER10	00h	0008 7210h	8
Interrupt request enable register 11	IER11	00h	0008 7211h	8
Interrupt request enable register 12	IER12	00h	0008 7212h	8
Interrupt request enable register 13	IER13	00h	0008 7213h	8
Interrupt request enable register 15	IER15	00h	0008 7215h	8
Interrupt request enable register 16	IER16	00h	0008 7216h	8
Interrupt request enable register 17	IER17	00h	0008 7217h	8
Interrupt request enable register 18	IER18	00h	0008 7218h	8
Interrupt request enable register 1A	IER1A	00h	0008 721Ah	8
Interrupt request enable register 1B	IER1B	00h	0008 721Bh	8
Interrupt request enable register 1C	IER1C	00h	0008 721Ch	8
Interrupt request enable register 1E	IER1E	00h	0008 721Eh	8
Interrupt request enable register 1F	IER1F	00h	0008 721Fh	8
Software interrupt activation register	SWINTR	00h	0008 72E0h	8
Fast interrupt set register	FIR	0000h	0008 72F0h	16
Interrupt source priority register 00	IPR00	00h	0008 7300h	8
Interrupt source priority register 01	IPR01	00h	0008 7301h	8
Interrupt source priority register 02	IPR02	00h	0008 7302h	8
Interrupt source priority register 03	IPR03	00h	0008 7303h	8
Interrupt source priority register 04	IPR04	00h	0008 7304h	8
Interrupt source priority register 05	IPR05	00h	0008 7305h	8
Interrupt source priority register 06	IPR06	00h	0008 7306h	8
Interrupt source priority register 07	IPR07	00h	0008 7307h	8
Interrupt source priority register 14	IPR14	00h	0008 7314h	8
Interrupt source priority register 18	IPR18	00h	0008 7318h	8

Table 11.3 Registers of the Interrupt Controller (6 / 7)

Register Name	Symbol	Value after Reset	Address	Access Size
Interrupt source priority register 20	IPR20	00h	0008 7320h	8
Interrupt source priority register 21	IPR21	00h	0008 7321h	8
Interrupt source priority register 22	IPR22	00h	0008 7322h	8
Interrupt source priority register 23	IPR23	00h	0008 7323h	8
Interrupt source priority register 24	IPR24	00h	0008 7324h	8
Interrupt source priority register 25	IPR25	00h	0008 7325h	8
Interrupt source priority register 26	IPR26	00h	0008 7326h	8
Interrupt source priority register 27	IPR27	00h	0008 7327h	8
Interrupt source priority register 40	IPR40	00h	0008 7340h	8
Interrupt source priority register 44	IPR44	00h	0008 7344h	8
Interrupt source priority register 48	IPR48	00h	0008 7348h	8
Interrupt source priority register 49	IPR49	00h	0008 7349h	8
Interrupt source priority register 51	IPR51	00h	0008 7351h	8
Interrupt source priority register 52	IPR52	00h	0008 7352h	8
Interrupt source priority register 53	IPR53	00h	0008 7353h	8
Interrupt source priority register 54	IPR54	00h	0008 7354h	8
Interrupt source priority register 55	IPR55	00h	0008 7355h	8
Interrupt source priority register 56	IPR56	00h	0008 7356h	8
Interrupt source priority register 57	IPR57	00h	0008 7357h	8
Interrupt source priority register 58	IPR58	00h	0008 7358h	8
Interrupt source priority register 59	IPR59	00h	0008 7359h	8
Interrupt source priority register 5A	IPR5A	00h	0008 735Ah	8
Interrupt source priority register 5B	IPR5B	00h	0008 735Bh	8
Interrupt source priority register 5C	IPR5C	00h	0008 735Ch	8
Interrupt source priority register 5D	IPR5D	00h	0008 735Dh	8
Interrupt source priority register 5E	IPR5E	00h	0008 735Eh	8
Interrupt source priority register 5F	IPR5F	00h	0008 735Fh	8
Interrupt source priority register 60	IPR60	00h	0008 7360h	8
Interrupt source priority register 67	IPR67	00h	0008 7367h	8
Interrupt source priority register 68	IPR68	00h	0008 7368h	8
Interrupt source priority register 69	IPR69	00h	0008 7369h	8
Interrupt source priority register 6A	IPR6A	00h	0008 736Ah	8
Interrupt source priority register 6B	IPR6B	00h	0008 736Bh	8
Interrupt source priority register 6C	IPR6C	00h	0008 736Ch	8
Interrupt source priority register 6D	IPR6D	00h	0008 736Dh	8
Interrupt source priority register 6E	IPR6E	00h	0008 736Eh	8
Interrupt source priority register 6F	IPR6F	00h	0008 736Fh	8
Interrupt source priority register 80	IPR80	00h	0008 7380h	8
Interrupt source priority register 81	IPR81	00h	0008 7381h	8
Interrupt source priority register 82	IPR82	00h	0008 7382h	8
Interrupt source priority register 88	IPR88	00h	0008 7388h	8
Interrupt source priority register 89	IPR89	00h	0008 7389h	8
Interrupt source priority register 8A	IPR8A	00h	0008 738Ah	8
Interrupt source priority register 8B	IPR8B	00h	0008 738Bh	8
Interrupt source priority register 90	IPR90	00h	0008 7390h	8

Table 11.3 Registers of the Interrupt Controller (7 / 7)

Register Name	Symbol	Value after Reset	Address	Access Size
IRQ control register 0	IRQCR0	00h	0008 7500h	8
IRQ control register 1	IRQCR1	00h	0008 7501h	8
IRQ control register 2	IRQCR2	00h	0008 7502h	8
IRQ control register 3	IRQCR3	00h	0008 7503h	8
IRQ control register 4	IRQCR4	00h	0008 7504h	8
IRQ control register 5	IRQCR5	00h	0008 7505h	8
IRQ control register 6	IRQCR6	00h	0008 7506h	8
IRQ control register 7	IRQCR7	00h	0008 7507h	8
Non-maskable interrupt status register	NMISR	00h	0008 7580h	8
Non-maskable interrupt enable register	NMIER	00h	0008 7581h	8
Non-maskable interrupt clear register	NMICLR	00h	0008 7582h	8
NMI pin interrupt control register	NMICR	00h	0008 7583h	8

11.2.1 Interrupt Request Register i (IRi) (i = interrupt vector number)

Address: 0008 7010h to 0008 70FEh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	IR
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	IR	Interrupt Status Flag	0: No interrupt request is generated 1: An interrupt request is generated	R/W*1
b7 to b1	—	Reserved	These bits are read as 0. The write value should always be 0.	R/W

Note 1. For edge-detected sources, only 0 can be written to this bit, which clears the flag, and writing 1 to the bit is enabled under the condition described in section 11.7, Usage Notes. For a level detection source, neither 0 nor 1 can be written.

The IRi register indicates interrupt request status.
IRi is provided for each interrupt source, where "i" indicates the interrupt vector number.
For the correspondence between interrupt sources and interrupt vector numbers, see Table 11.4, Interrupt Vector Table.

IR Flag (Interrupt Status Flag)

This bit is the status flag of an individual interrupt request. This flag is set to 1 when the corresponding interrupt request is generated. For the actual interrupt to be generated, interrupt output by the corresponding peripheral module should be enabled in the case of peripheral-module interrupts.
The form of detection for an interrupt request is either edge detection or level detection. For interrupts from peripheral modules, either edge detection or level detection is determined per interrupt source. For interrupts from IRQn pins, edge detection or level detection is selected by the setting of the IRQMD[1:0] bits in the corresponding IRQCRn (n= 0 to 7).
Regarding detection of the various interrupt sources, see Table 11.4, Interrupt Vector Table.

(1) Edge detection

[Setting condition]

- The flag is set to 1 in response to the generation of an interrupt request from the corresponding peripheral module or IRQn pin. For interrupt generation by the various peripheral modules, refer to the sections describing the modules.
- Though writing 1 to the IR flag is prohibited, it is enabled under the condition described in Table 11.7, Usage Notes.

[Clearing conditions]

- The flag is cleared to 0 when the interrupt request destination accepts the interrupt request.
- The IR flag is cleared to 0 by writing 0 to it. Note that writing 0 to the IR flag is prohibited if the interrupt request destination is the DTC.

(2) Level detection

[Setting condition]

- The flag remains set to 1 while an interrupt request is being sent from the corresponding peripheral module or IRQn pin. For interrupt generation in each peripheral module, refer to the section describing the module.

[Clearing conditions]

- The flag is cleared to 0 when the source of the interrupt request is cleared. (This flag is not cleared even when the interrupt request destination accepts the interrupt request.) For interrupt clearing in each peripheral module, refer to the section describing the module.

When level detection has been selected for an IRQn pin, the interrupt request is withdrawn by driving the IRQn pin high. Do not write 0 or 1 to the IR flag while level detection is selected.

11.2.2 Interrupt Request Enable Register m (IERm) (m = 02h to 1Fh)

Address: 0008 7202h to 0008 721Fh

	b7	b6	b5	b4	b3	b2	b1	b0
	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	IEN0	Interrupt Request Enable 0	0: Interrupt request is disabled 1: Interrupt request is enabled	R/W
b1	IEN1	Interrupt Request Enable 1		R/W
b2	IEN2	Interrupt Request Enable 2		R/W
b3	IEN3	Interrupt Request Enable 3		R/W
b4	IEN4	Interrupt Request Enable 4		R/W
b5	IEN5	Interrupt Request Enable 5		R/W
n6	IEN6	Interrupt Request Enable 6		R/W
b7	IEN7	Interrupt Request Enable 7		R/W

Note 1. Write 0 to the bit that corresponds to the vector number for reservation. Such the bit is read as 0.

The IERm register is used to enable or disable an interrupt request to the CPU and a DTC activation request.

IENj Bits (Interrupt Request Enable) (j = 7 to 0)

When an IENj bit is 1, the corresponding interrupt request will be output to the interrupt request destination.
When an IENj bit is 0, the corresponding interrupt request will not be output to the interrupt request destination.
The setting of an IERm.IENj bit does not affect the IRi.IR flag. Even when the IERm.IENj bit is 0, the IRi.IR flag value changes according to the conditions described in section 11.2.1, Interrupt Request Register i (IRi) (i = interrupt vector number).
The IERm.IENj bit is set for each request source (vector number).
For the correspondence between interrupt sources and IERm.IENj bits, see Table 11.4, Interrupt Vector Table.
For the IERm.IENj bit setting procedure during interrupt request destination selection, refer to Table 11.4.3, Selecting Interrupt Request Destinations.

11.2.3 Interrupt Priority Register m (IPRm) (m = 00h to 90h)

Address: 0008 7300h to 0008 7390Fh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	IPR[3:0]			
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b3 to b0	IPR[3:0]	Interrupt Priority Level Select	b3 b0 0 0 0 0: Level 0 (interrupt prohibited) 0 0 0 1: Level 1 0 0 1 0 : Level 2 0 0 1 1 : Level 3 0 1 0 0 : Level 4 0 1 0 1 : Level 5 0 1 1 0 : Level 6 0 1 1 1 : Level 7 1 0 0 0 : Level 8 1 0 0 1 : Level 9 1 0 1 0 : Level 10 1 0 1 1 : Level 11 1 1 0 0 : Level 12 1 1 0 1 : Level 13 1 1 1 0 : Level 14 1 1 1 1: Level 15 (highest)	R/W
b7 to b4	—	Reserved	These bits are read as 0. The write value should always be 0.	R/W

The IPRm register is used to set the priority level of an interrupt source.
IPRm exists for each interrupt source group, where m is the serial number from 00h to 90h.
For the correspondence between interrupt sources and groups, see Table 11.4, Interrupt Vector Table.

IPR[3:0] Bits (Interrupt Priority Level Select)

These bits specify the priority level of the corresponding interrupt source.
Priority levels specified by the IPR[3:0] bits are used only to determine the priority of interrupt requests to be transferred to the CPU, and do not affect transfer requests to the DTC.
The CPU accepts only interrupt requests higher than the priority level specified by the IPL[3:0] bits in PSW, and handles accepted interrupts.
If two or more interrupt requests are generated at the same time, their priority levels are compared with the value of the IPR[3:0] bits. If interrupt requests of the same priority level are generated at the same time, an interrupt source with a smaller vector number takes precedence.
These bits should be written to while an interrupt request is disabled (the IERm.IENj bit = 0).

11.2.4 Fast Interrupt Register (FIR)

Address: 0008 72F0h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	FIEN	—	—	—	—	—	—	—	FVCT[7:0]							
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b7 to b0	FVCT[7:0]	Fast Interrupt Vector Number	Specify the vector number of an interrupt source to be a fast interrupt.	R/W
b14 to b8	—	Reserved	These bits are read as 0. The write value should always be 0.	R/W
b15	FIEN	Fast Interrupt Enable	0: Fast interrupt is disabled 1: Fast interrupt is enabled	R/W

The FIR register is used to set the fast interrupt function.
The fast interrupt function based on the FIR register setting is applicable only to interrupts to the CPU. It will not affect any transfer request to the DTC.
Before writing to this register, be sure to disable interrupt requests (IERm.IENj bit = 0).

FVCT[7:0] Bits (Fast Interrupt Vector Number)

The FVCT[7:0] bits specify the vector number of an interrupt source that uses the fast interrupt function.

FIEN Bit (Fast Interrupt Enable)

This bit enables fast interrupt.
Setting this bit to 1 makes the interrupt request of the vector number specified by the FVCT[7:0] bits a fast interrupt.
When an interrupt request of the vector number specified by the FVCT[7:0] bits is generated and the interrupt request destination is the CPU while the FIEN bit is 1, the interrupt request is output to the CPU as a fast interrupt regardless of the setting of the IPRm register. When using the fast interrupt for returning from the software standby mode, see Return from Software Standby Mode, Return from Software Standby Mode.
If the setting of the IERm.IENj (m = 02h to 1Fh, j =7 to 0) bit has disabled interrupt requests from the interrupt source with the vector number in this register, fast interrupt requests are not output to the CPU.
For settable vector numbers, see Table 11.4, Interrupt Vector Table.
Do not write any reserved vector numbers to the FVCT[7:0] bits.
For details of fast interrupt, see section 10, Exceptions, and section section 11.4.5, Fast Interrupt.

11.2.5 Software Interrupt Activation Register (SWINTR)

Address: 0008 72F0h

	b7	b6	b5	b4	b3	b2	b1
	—	—	—	—	—	—	SWINT
Value after reset:	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	SWINT	Software Interrupt Activation	This bit is read as 0. Writing 1 issues a software interrupt request. Writing 0 to this bit has no effect.	R/W*1
b7 to b1	—	Reserved	These bits are read as 0. The write value should always be 0.	R/W

Note 1. Only 1 can be written. This bit is read as 0.

The SWINTR register is used to issue a software interrupt request.

SWINT Bit (Software Interrupt Activation)

When 1 is written to the SWINT bit, the interrupt request register 27 (IR27) is set to 1.
If 1 is written to the SWINT bit when the DTC activation enable register 27 (DTCER27) is set to 0, an interrupt to the CPU is generated.
If 1 is written to the SWINT bit when the DTC activation enable register 27 (DTCER27) is set to 1, a DTC activation request is issued.

11.2.6 DTC Activation Enable Register n (DTCERn) (n = interrupt vector number)

Address: 0008 711Bh to 0008 71FEh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	DTCE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	DTCE	DTC Activation Enable	0: DTC activation is disabled 1: DTC activation is enabled	R/W
b7 to b1	—	Reserved	These bits are read as 0. The write value should always be 0.	R/W

The DTCERn register is used to select an interrupt source to activate the DTC.

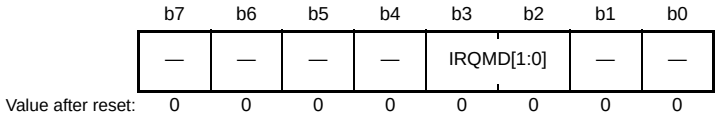
DTCE Bit (DTC Activation Enable)

When the DTCE bit is set to 1, the corresponding interrupt source is selected as the source for the DTC activation.

[Setting condition]
When 1 is written to the DTCE bit
[Clearing conditions]
When the specified number of transfers is completed (for the chain transfer, the number of transfers for the last chain transfer is completed)
When 0 is written to the DTCE bit

11.2.7 IRQ Control Register n (IRQCRn) (n = 0 to 7)

Address: 0008 7500h to 0008 7507h



Bit	Symbol	Bit Name	Description	R/W
b1, b0	—	Reserved	These bits are read as 0. The write value should always be 0.	R/W
b3, b2	IRQMD[1:0]	IRQ Detection Sense Select	b3 b2 0 0: Low level 0 1: Falling edge 1 0: Rising edge 1 1: Rising and falling edges	R/W
b7 to b4	—	Reserved	These bits are read as 0. The write value should always be 0.	R/W

The IRQCRn register is used to set the external interrupt IRQn pin (n = 7 to 0).
Modify the settings of this register when the interrupt request of the corresponding interrupt request enable bit is prohibited (IENj bit in IERm is 0). After changing the value of the register, clear the IR flag in IRi and then set the interrupt request enable bit to enable the request. However, the IR flag need not be cleared if the change was to the low level.

IRQMD[1:0] Bits (IRQ Detection Sense Select)

These bits select the detection sensing method of external pin interrupt sources IRQ7 to IRQ0.
For the external pin interrupt detection setting, see Table 11.4.6, External Pin Interrupts.

11.2.8 Non-Maskable Interrupt Status Register (NMISR)

Address: 0008 7580h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	OSTST	LVDST	NMIST
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	NMIST	NMI Status Flag	0: NMI pin interrupt is not requested 1: NMI pin interrupt is requested	R
b1	LVDST	Voltage-Monitoring Interrupt Detection Status Flag	0: Voltage-monitoring interrupt is not requested 1: Voltage-monitoring interrupt is requested	R
b2	OSTST	Oscillation Stop Detection Interrupt Status Flag	0: Oscillation stop detection interrupt is not requested 1: Oscillation stop detection interrupt is requested	R
b7 to b3	—	Reserved	These bits are read as 0 and cannot be modified.	R

The NMISR register monitors the status of a non-maskable interrupt source. Writing to the NMISR register is ignored. The setting in the non-maskable interrupt enable register (NMIER) does not affect the status flags in NMISR.
Before ending from the non-maskable interrupt routine, read the NMISR register and confirm the generation status of other non-maskable interrupts. Make sure to end from the routine after confirming that all the bits in the NMISR register are set to 0. Make sure to end from the handler after confirming that all the bits in the NMISR register are set to 0.

NMIST Flag (NMI Status Flag)

This flag indicates the NMI pin interrupt request.
The NMIST flag is read-only, and cleared by the NMICLR.NMICLR bit.
[Setting condition]
When an edge specified by the NMICR.NMIMD bit is input to the NMI pin
[Clearing condition]
When 1 is written to the NMICLR.NMICLR bit

LVDST Flag (Voltage-Monitoring Interrupt Status Flag)

This flag indicates the request for voltage-monitoring interrupt.
[Setting condition]

- When the voltage-monitoring interrupt is generated while it is enabled by the generation source

[Clearing condition]

- When the interrupt is cleared by the generation source

OSTST Flag (Oscillation Stop Detection Interrupt Status Flag)

This flag indicates the request for oscillation stop detection interrupt.
The OSTST flag is read-only, and cleared by NMICLR.OSTCLR bit.
[Setting condition]

- When oscillation stop detection interrupt is generated while it is enabled by the generation source

[Clearing condition]

- When 1 is written to the NMICLR.OSTCLR bit

11.2.9 Non-Maskable Interrupt Enable Register (NMIER)

Address: 0008 7581h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	OSTEN	LVDEN	NMIEN
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	NMIEN	NMI Pin Interrupt Enable	0: NMI pin interrupt is disabled 1: NMI pin interrupt is enabled	R/(W)*1
b1	LVDEN	Voltage-Monitoring Interrupt Enable	0: Voltage-monitoring interrupt is disabled 1: Voltage-monitoring interrupt is enabled	R/(W)*1
b2	OSTEN	Oscillation Stop Detection Interrupt Enable	0: Oscillation stop detection interrupt is disable 1: Oscillation stop detection interrupt is enabled	R/(W)*1
b7 to b3	—	Reserved	These bits are read as 0. The write value should always be 0.	R/W

Note 1. A 1 can be written to this bit only once, and subsequent write accesses are no longer enabled.

The NMIER register enables/disables a non-maskable interrupt source.

NMIEN Bit (NMI Pin Interrupt Enable)

This bit enables the NMI pin interrupt.
A 1 can be written to this bit only once, and subsequent write accesses are no longer enabled.
Once the NMI pin interrupt is enabled, the interrupt cannot be canceled and writing 0 to this bit is disabled.

LVDEN Bit (Voltage-Monitoring Interrupt Enable)

This bit enables the voltage-monitoring interrupt.
A 1 can be written to this bit only once, and subsequent write accesses are no longer enabled.
Once the voltage-monitoring interrupt is enabled, the interrupt cannot be canceled and writing 0 to this bit is disabled.

OSTEN Bit (Oscillation Stop Detection Interrupt Enable)

This bit enables the oscillation stop detection interrupt.
A 1 can be written to this bit only once, and subsequent write accesses are no longer enabled.
Once the oscillation stop detection interrupt is enabled, the interrupt cannot be canceled and writing 0 to this bit is disabled.

11.2.10 Non-Maskable Interrupt Clear Register (NMICLR)

Address: 0008 7582h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	OSTCLR	—	NMICLR
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	NMICLR	NMI Clear	This bit is always read as 0. Writing 1 to this bit clears the NMISR.NMIST flag. Writing 0 to this bit has no effect.	R/(W)*1
b1	—	Reserved	This bit is read as 0. The write value should always be 0.	R/W
b2	OSTCLR	OST Clear	This bit is always read as 0. Writing 1 to this bit clears the NMISR.OSTST flag. Writing 0 to this bit has no effect.	R/(W)*2
b7 to b3	—	Reserved	These bits are read as 0. The write value should always be 0.	R/W

Note 1. Only 1 can be written to this bit, to clear the NMISR.NMIST flag.
Note 2. Only 1 can be written to this bit, to clear the NMISR.OSTST flag.

The NMICLR register is used to clear the non-maskable interrupt status register (NMISR).

NMICLR Bit (NMI Clear)

Writing 1 to the NMICLR bit clears the NMISR.NMIST flag.

The NMICLR bit does not retain the "1" state. This bit is always read as 0.

OSTCLR Bit (OST Clear)

Writing 1 to the OSTCLR bit clears the NMISR.OSTST flag.

The OSTCLR bit does not retain the "1" state. This bit is always read as 0.

11.2.11 NMI Pin Interrupt Control Register (NMICR)

Address: 0008 7583h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	NMIMD	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b2 to b0	—	Reserved	These bits are read as 0. The write value should always be 0.	R/W
b3	NMIMD	NMI Detection Set	0: Falling edge 1: Rising edge	R/(W)
b7 to b4	—	Reserved	These bits are read as 0. The write value should always be 0.	R/W

The NMICR register is used to set the NMI pin interrupt.
Change the setting of the NMICR register before the NMI pin interrupt is enabled (before 1 is written to the NMIER.NMIEN bit).

NMIMD Bit (NMI Detection Set)

This bit specifies the detection edge of the NMI pin interrupt.

11.3 Vector Table

There are two types of interrupts: maskable interrupts and non-maskable interrupts. Hereinafter "interrupts" is exclusively used to indicate maskable interrupts, i.e. interrupts other than the non-maskable interrupt.
When the CPU accepts an interrupt or non-maskable interrupt, it acquires a four-byte vector address from the vector table.

11.3.1 Interrupt Vector Table

The interrupt vector table is placed in the 1024-byte range (4 bytes x 256 sources) beginning at the address specified in the interrupt table register (INTB) of the CPU. Write a value to the INTB register before enabling interrupts. The value written to the INTB register should be a multiple of 4.
Table 11.4 shows the interrupt vector table. In the table, "sstb return" indicates return from the standby mode, and "Sacs return" indicates return from all-module clock stop mode.

Table 11.4 Interrupt Vector Table (1 / 7)

Priority	Source of Interrupt Request	Name	Vector No.	Vector Address Offset	Form of Detection	Selectable Interrupt Request Destination		sstb Return	sacs Return	IER	IPR
						CPU	DTC				
High	—	Reserved	0	0000h	—	×	×	×	×	—	—
		Reserved	1	0004h	—	×	×	×	×	—	—
		Reserved	2	0008h	—	×	×	×	×	—	—
		Reserved	3	000Ch	—	×	×	×	×	—	—
		Reserved	4	0010h	—	×	×	×	×	—	—
		Reserved	5	0014h	—	×	×	×	×	—	—
		Reserved	6	0018h	—	×	×	×	×	—	—
		Reserved	7	001Ch	—	×	×	×	×	—	—
		Reserved	8	0020h	—	×	×	×	×	—	—
		Reserved	9	0024h	—	×	×	×	×	—	—
		Reserved	10	0028h	—	×	×	×	×	—	—
		Reserved	11	002Ch	—	×	×	×	×	—	—
		Reserved	12	0030h	—	×	×	×	×	—	—
		Reserved	13	0034h	—	×	×	×	×	—	—
		Reserved	14	0038h	—	×	×	×	×	—	—
		Reserved	15	003Ch	—	×	×	×	×	—	—
	Bus error	BUSERR	16	0040h	Level	√	×	×	×	IER02.IEN0	IPR00
	—	Reserved	17	0044h	—	×	×	×	×	IER02.IEN1	—
	—	Reserved	18	0048h	—	×	×	×	×	IER02.IEN2	—
		Reserved	19	004Ch	—	×	×	×	×	IER02.IEN3	—
		Reserved	20	0050h	—	×	×	×	×	IER02.IEN4	—
	FCUIF	FIFERR	21	0054h	Level	√	×	×	×	IER02.IEN5	IPR01
		Reserved	22	0058h	—	×	×	×	×	IER02.IEN6	—
		FRDYI	23	005Ch	Edge	√	×	×	×	IER02.IEN7	IPR02
	—	Reserved	24	0060h	—	×	×	×	×	IER03.IEN0	—
	—	Reserved	25	0064h	—	×	×	×	×	IER03.IEN1	—
	—	Reserved	26	0068h	—	×	×	×	×	IER03.IEN2	—
	ICU	SWINT	27	006Ch	Edge	√	√	×	×	IER03,IEN3	IPR03
Low	CMT0	CMI0	28	0070h	Edge	√	√	×	×	IER03.IEN4	IPR04

Table 11.4 Interrupt Vector Table (2 / 7)

Priority	Source of Interrupt Request	Name	Vector No.	Vector Address Offset	Form of Detection	Selectable Interrupt Request Destination		sstb Return	sacs Return	IER	IPR
						CPU	DTC				
High	CMT1	CMI1	29	0074h	Edge	√	√	×	×	IER03.IEN5	IPR05
	CMT2	CMI2	30	0078h	Edge	√	√	×	×	IER03.IEN6	IPR06
	CMT3	CMI3	31	007Ch	Edge	√	√	×	×	IER03.IEN7	IPR07
	—	Reserved	32	0080h	—	×	×	×	×	IER04.IEN0	—
		Reserved	33	0084h	—	×	×	×	×	IER04.IEN1	—
		Reserved	34	0088h	—	×	×	×	×	IER04.IEN2	—
		Reserved	35	008Ch	—	×	×	×	×	IER04.IEN3	—
		Reserved	36	0090h	—	×	×	×	×	IER04.IEN4	—
		Reserved	37	0094h	—	×	×	×	×	IER04.IEN5	—
		Reserved	38	0098h	—	×	×	×	×	IER04.IEN6	—
		Reserved	39	009Ch	—	×	×	×	×	IER04.IEN7	—
		Reserved	40	00A0h	—	×	×	×	×	IER05.IEN0	—
		Reserved	41	00A4h	—	×	×	×	×	IER05.IEN1	—
		Reserved	42	00A8h	—	×	×	×	×	IER05.IEN2	—
		Reserved	43	00ACh	—	×	×	×	×	IER05.IEN3	—
	RSPI0	SPEI0	44	00B0h	Level	√	×	×	×	IER05.IEN4	IPR14
		SPRI0	45	00B4h	Edge	√	√	×	×	IER05.IEN5	
		SPTI0	46	00B8h	Edge	√	√	×	×	IER05.IEN6	
		SPII0	47	00BCh	Level	√	×	×	×	IER05.IEN7	
	—	Reserved	48	00C0h	—	×	×	×	×	IER06.IEN0	—
		Reserved	49	00C4h	—	×	×	×	×	IER06.IEN1	—
		Reserved	50	00C8h	—	×	×	×	×	IER06.IEN2	—
		Reserved	51	00CCh	—	×	×	×	×	IER06.IEN3	—
		Reserved	52	00D0h	—	×	×	×	×	IER06.IEN4	—
		Reserved	53	00D4h	—	×	×	×	×	IER06.IEN5	—
		Reserved	54	00D8h	—	×	×	×	×	IER06.IEN6	—
		Reserved	55	00DCh	—	×	×	×	×	IER06.IEN7	—
	CAN0	ERS0	56	00E0h	Edge	√	×	×	×	IER07.IEN0	IPR18
		RXF0	57	00E4h	Edge	√	×	×	×	IER07.IEN1	
		TXF0	58	00E8h	Edge	√	×	×	×	IER07.IEN2	
		RXM0	59	00ECh	Edge	√	×	×	×	IER07.IEN3	
		TXM0	60	00F0h	Edge	√	×	×	×	IER07.IEN4	
	—	Reserved	61	00F4h	—	×	×	×	×	IER07.IEN5	—
		Reserved	62	00F8h	—	×	×	×	×	IER07.IEN6	—
Low		Reserved	63	00FCh	—	×	×	×	×	IER07.IEN7	—

Table 11.4 Interrupt Vector Table (3 / 7)

Priority	Source of Interrupt Request	Name	Vector No.	Vector Address Offset	Form of Detection	Selectable Interrupt Request Destination		sstb Return	sacs Return	IER	IPR
						CPU	DTC				
High	External pin	IRQ0	64	0100h	Edge / Level	√	√	√	√	IER08.IEN0	IPR20
		IRQ1	65	0104h	Edge / Level	√	√	√	√	IER08.IEN1	IPR21
		IRQ2	66	0108h	Edge / Level	√	√	√	√	IER08.IEN2	IPR22
		IRQ3	67	010Ch	Edge / Level	√	√	√	√	IER08.IEN3	IPR23
		IRQ4	68	0110h	Edge / Level	√	√	√	√	IER08.IEN4	IPR24
		IRQ5	69	0114h	Edge / Level	√	√	√	√	IER08.IEN5	IPR25
		IRQ6	70	0118h	Edge / Level	√	√	√	√	IER08.IEN6	IPR26
		IRQ7	71	011Ch	Edge / Level	√	√	√	√	IER08.IEN7	IPR27
		Reserved	72	0120h	—	×	×	×	×	IER09.IEN0	—
		Reserved	73	0124h	—	×	×	×	×	IER09.IEN1	—
		Reserved	74	0128h	—	×	×	×	×	IER09.IEN2	—
		Reserved	75	012Ch	—	×	×	×	×	IER09.IEN3	—
		Reserved	76	0130h	—	×	×	×	×	IER09.IEN4	—
		Reserved	77	0134h	—	×	×	×	×	IER09.IEN5	—
		Reserved	78	0138h	—	×	×	×	×	IER09.IEN6	—
		Reserved	79	013Ch	—	×	×	×	×	IER09.IEN7	—
		Reserved	80	0140h	—	×	×	×	×	IER0A.IEN0	—
		Reserved	81	0144h	—	×	×	×	×	IER0A.IEN1	—
		Reserved	82	0148h	—	×	×	×	×	IER0A.IEN2	—
		Reserved	83	014Ch	—	×	×	×	×	IER0A.IEN3	—
		Reserved	84	0150h	—	×	×	×	×	IER0A.IEN4	—
		Reserved	85	0154h	—	×	×	×	×	IER0A.IEN5	—
		Reserved	86	0158h	—	×	×	×	×	IER0A.IEN6	—
		Reserved	87	015Ch	—	×	×	×	×	IER0A.IEN7	—
	—	Reserved	88	0160h	—	×	×	×	×	IER0B.IEN0	—
		Reserved	89	0164h	—	×	×	×	×	IER0B.IEN1	—
		Reserved	90	0168h	—	×	×	×	×	IER0B.IEN2	—
		Reserved	91	016Ch	—	×	×	×	×	IER0B.IEN3	—
		Reserved	92	0170h	—	×	×	×	×	IER0B.IEN4	—
		Reserved	93	0174h	—	×	×	×	×	IER0B.IEN5	—
		Reserved	94	0178h	—	×	×	×	×	IER0B.IEN6	—
		Reserved	95	017Ch	—	×	×	×	×	IER0B.IEN7	—
	WDT	WOVI	96	0180h	Edge	√	—	—	√	IER0C.IEN0	IPR40
		Reserved	97	0184h	—	×	×	×	×	IER0C.IEN1	—
	AD0	ADI0	98	0188h	Edge	√	√	—	—	IER0C.IEN2	IPR44
	—	Reserved	99	018Ch	—	×	×	×	×	IER0C.IEN3	—
		Reserved	100	0190h	—	×	×	×	×	IER0C.IEN4	—
		Reserved	101	0194h	—	×	×	×	×	IER0C.IEN5	—
	S12AD0	S12ADI0	102	0198h	Edge	√	√	×	×	IER0C.IEN6	IPR48
	S12AD1	S12ADI1	103	019Ch	Edge	√	√	×	×	IER0C.IEN7	
	—	Reserved	104	01A0h	—	×	×	×	×	IER0D.IEN0	—
Low		Reserved	105	01A4h	—	×	×	×	×	IER0D.IEN1	—

Table 11.4 Interrupt Vector Table (4 / 7)

Priority	Source of Interrupt Request	Name	Vector No.	Vector Address Offset	Form of Detection	Selectable Interrupt Request Destination		sstb Return	sacs Return	IER	IPR
						CPU	DTC				
High	Comparator	CMPI	106	01A8h	Edge	√	√	×	×	IER0D.IEN2	IPR49
	—	Reserved	107	01ACh	—	×	×	×	×	IER0D.IEN3	—
		Reserved	108	01B0h	—	×	×	×	×	IER0D.IEN4	—
		Reserved	109	01B4h	—	×	×	×	×	IER0D.IEN5	—
		Reserved	110	01B8h	—	×	×	×	×	IER0D.IEN6	—
		Reserved	111	01BCh	—	×	×	×	×	IER0D.IEN7	—
		Reserved	112	01C0h	—	×	×	×	×	IER0E.IEN0	—
		Reserved	113	01C4h	—	×	×	×	×	IER0E.IEN1	—
	MTU0	TGIA0	114	01C8h	Edge	√	√	×	×	IER0E.IEN2	IPR51
		TGIB0	115	01CCh	Edge	√	√	×	×	IER0E.IEN3	
		TGIC0	116	01D0h	Edge	√	√	×	×	IER0E.IEN4	
		TGID0	117	01D4h	Edge	√	√	×	×	IER0E.IEN5	
		TCIV0	118	01D8h	Edge	√	×	×	×	IER0E.IEN6	IPR52
		TGIE0	119	01DCh	Edge	√	×	×	×	IER0E.IEN7	
		TGIF0	120	01E0h	Edge	√	×	×	×	IER0F.IEN0	
	MTU1	TGIA1	121	01E4h	Edge	√	√	×	×	IER0F.IEN1	IPR53
		TGIB1	122	01E8h	Edge	√	√	×	×	IER0F.IEN2	
		TCIV1	123	01ECh	Edge	√	×	×	×	IER0F.IEN3	IPR54
		TCIU1	124	01F0h	Edge	√	×	×	×	IER0F.IEN4	
	MTU2	TGIA2	125	01F4h	Edge	√	√	×	×	IER0F.IEN5	IPR55
		TGIB2	126	01F8h	Edge	√	√	×	×	IER0F.IEN6	
		TCIV2	127	01FCh	Edge	√	×	×	×	IER0F.IEN7	IPR56
		TCIU2	128	0200h	Edge	√	×	×	×	IER10.IEN0	
	MTU3	TGIA3	129	0204h	Edge	√	√	×	×	IER10.IEN1	IPR57
		TGIB3	130	0208h	Edge	√	√	×	×	IER10.IEN2	
		TGIC3	131	020Ch	Edge	√	√	×	×	IER10.IEN3	
		TGID3	132	0210h	Edge	√	√	×	×	IER10.IEN4	
		TCIV3	133	0214h	Edge	√	×	×	×	IER10.IEN5	IPR58
	MTU4	TGIA4	134	0218h	Edge	√	√	×	×	IER10.IEN6	IPR59
		TGIB4	135	021Ch	Edge	√	√	×	×	IER10.IEN7	
		TGIC4	136	0220h	Edge	√	√	×	×	IER11.IEN0	
		TGID4	137	0224h	Edge	√	√	×	×	IER11.IEN1	
		TCIV4	138	0228h	Edge	√	√	×	×	IER11.IEN2	IPR5A
	MTU5	TGIU5	139	022Ch	Edge	√	√	×	×	IER11.IEN3	IPR5B
		TGIV5	140	0230h	Edge	√	√	×	×	IER11.IEN4	
Low		TGIW5	141	0234h	Edge	√	√	×	×	IER11.IEN5	

Table 11.4 Interrupt Vector Table (5 / 7)

Priority	Source of Interrupt Request	Name	Vector No.	Vector Address Offset	Form of Detection	Selectable Interrupt Request Destination		sstb Return	sacs Return	IER	IPR
						CPU	DTC				
High	MTU6	TGIA6	142	0238h	Edge	√	√	×	×	IER11.IEN6	IPR5C
		TGIB6	143	023Ch	Edge	√	√	×	×	IER11.IEN7	
		TGIC6	144	0240h	Edge	√	√	×	×	IER12.IEN0	
		TGID6	145	0244h	Edge	√	√	×	×	IER12.IEN1	
		TCIV6	146	0248h	Edge	√	×	×	×	IER12.IEN2	IPR5D
		Reserved	147	024Ch	—	×	×	—	—	IER12.IEN3	
		Reserved	148	0250h	—	×	×	—	—	IER12.IEN4	
	MTU7	TGIA7	149	0254h	Edge	√	√	×	×	IER12.IEN5	IPR5E
		TGIB7	150	0258h	Edge	√	√	×	×	IER12.IEN6	
		TGIC7	151	025Ch	Edge	√	√	×	×	IER12.IEN7	IPR5F
		TGID7	152	0260h	Edge	√	√	×	×	IER13.IEN0	
		TCIV7	153	0264h	Edge	√	√	×	×	IER13.IEN1	IPR60
	—	Reserved	154	0268h	—	×	×	×	×	IER13.IEN2	
		Reserved	155	026Ch	—	×	×	×	×	IER13.IEN3	—
		Reserved	156	0270h	—	×	×	×	×	IER13.IEN4	—
		Reserved	157	0274h	—	×	×	×	×	IER13.IEN5	—
		Reserved	158	0278h	—	×	×	×	×	IER13.IEN6	—
		Reserved	159	027Ch	—	×	×	×	×	IER13.IEN7	—
		Reserved	160	0280h	—	×	×	×	×	IER14.IEN0	—
		Reserved	161	0284h	—	×	×	×	×	IER14.IEN1	—
		Reserved	162	0288h	—	×	×	×	×	IER14.IEN2	—
		Reserved	163	028Ch	—	×	×	×	×	IER14.IEN3	—
		Reserved	164	0290h	—	×	×	×	×	IER14.IEN4	—
	—	Reserved	165	0294h	—	×	×	×	×	IER14.IEN5	—
		Reserved	166	0298h	—	×	×	×	×	IER14.IEN6	—
	—	Reserved	167	029Ch	—	×	×	×	×	IER14.IEN7	—
		Reserved	168	02A0h	—	×	×	×	×	IER15.IEN0	—
		Reserved	169	02A4h	—	×	×	×	×	IER15.IEN1	—
	POE	OEI1	170	02A8h	Level	√	×	×	×	IER15.IEN2	IPR67
		OEI2	171	02ACh	Level	√	×	×	×	IER15.IEN3	
		OEI3	172	02B0h	Level	√	×	×	×	IER15.IEN4	
		OEI4	173	02B4h	Level	√	×	×	×	IER15.IEN5	
	GPT0	GTCIA0	174	02B8h	Edge	√	√	×	×	IER15.IEN6	IPR68
		GTCIB0	175	02BCh	Edge	√	√	×	×	IER15.IEN7	
		GTCIC0	176	02C0h	Edge	√	√	×	×	IER16.IEN0	
		GTCIE0	177	02C4h	Edge	√	√	×	×	IER16.IEN1	IPR69
		GTCIV0	178	02C8h	Edge	√	√	×	×	IER16.IEN2	
Low		LOCO1	179	02CCh	Edge	√	√	×	×	IER16.IEN3	

Table 11.4 Interrupt Vector Table (6 / 7)

Priority	Source of Interrupt Request	Name	Vector No.	Vector Address Offset	Form of Detection	Selectable Interrupt Request Destination		sstb Return	sacs Return	IER	IPR
						CPU	DTC				
High	GPT1	GTCIA1	180	02D0h	Edge	√	√	×	×	IER16.IEN4	IPR6A
		GTCIB1	181	02D4h	Edge	√	√	×	×	IER16.IEN5	
		GTCIC1	182	02D8h	Edge	√	√	×	×	IER16.IEN6	
		GTCIE1	183	02DCh	Edge	√	√	×	×	IER16.IEN7	IPR6B
		GTCIV1	184	02E0h	Edge	√	√	×	×	IER17.IEN0	
		Reserved	185	02E4h	—	×	×	×	×	IER17.IEN1	—
	GPT2	GTCIA2	186	02E8h	Edge	√	√	×	×	IER17.IEN2	IPR6C
		GTCIB2	187	02ECh	Edge	√	√	×	×	IER17.IEN3	
		GTCIC2	188	02F0h	Edge	√	√	×	×	IER17.IER4	
		GTCIE2	189	02F4h	Edge	√	√	×	×	IER17.IEN5	IPR6D
		GTCIV2	190	02F8h	Edge	√	√	×	×	IER17.IEN6	
		Reserved	191	02FCh	—	×	×	×	×	IER17.IEN7	—
	GPT3	GTCIA3	192	0300h	Edge	√	√	×	×	IER18.IEN0	IPR6E
		GTCIB3	193	0304h	Edge	√	√	×	×	IER18.IEN1	
		GTCIC3	194	0308h	Edge	√	√	×	×	IER18.IEN2	
		GTCIE3	195	030Ch	Edge	√	√	×	×	IER18.IEN3	IPR6F
		GTCIV3	196	0310h	Edge	√	√	×	×	IER18.IEN4	
		Reserved	197	0314h	—	×	×	×	×	IER18.IEN5	
	—	Reserved	198	0318h	—	×	×	×	×	IER18.IEN6	—
		Reserved	199	031Ch	—	×	×	×	×	IER18.IEN7	—
		Reserved	200	0320h	—	×	×	×	×	IER19.IEN0	—
		Reserved	201	0324h	—	×	×	×	×	IER19.IEN1	—
		Reserved	202	0328h	—	×	×	×	×	IER19.IEN2	—
		Reserved	203	032Ch	—	×	×	×	×	IER19.IEN3	—
		Reserved	204	0330h	—	×	×	×	×	IER19.IEN4	—
		Reserved	205	0334h	—	×	×	×	×	IER19.IEN5	—
		Reserved	206	0338h	—	×	×	×	×	IER19.IEN6	—
		Reserved	207	033Ch	—	×	×	×	×	IER19.IEN7	—
		Reserved	208	0340h	—	×	×	×	×	IER1A.IEN0	—
		Reserved	209	0344h	—	×	×	×	×	IER1A.IEN1	—
	—	Reserved	210	0348h	—	×	×	×	×	IER1A.IEN2	—
		Reserved	211	034Ch	—	×	×	×	×	IER1A.IEN3	—
		Reserved	212	0350h	—	×	×	×	×	IER1A.IEN4	—
		Reserved	213	0354h	—	×	×	×	×	IER1A.IEN5	—
	SCI0	ERI0	214	0358h	Level	√	×	×	×	IER1A.IEN6	IPR80
		RXI0	215	035Ch	Edge	√	√	×	×	IER1A.IEN7	
		TXI0	216	0360h	Edge	√	√	×	×	IER1B.IEN0	
		TEI0	217	0364h	Level	√	×	×	×	IER1B.IEN1	
	SCI1	ERI1	218	0368h	Level	√	×	×	×	IER1B.IEN2	IPR81
		RXI1	219	036Ch	Edge	√	√	×	×	IER1B.IEN3	
		TXI1	220	0370h	Edge	√	√	×	×	IER1B.IEN4	
Low		TEI1	221	0374h	Level	√	×	×	×	IER1B.IEN5	

Table 11.4 Interrupt Vector Table (7 / 7)

Priority	Source of Interrupt Request	Name	Vector No.	Vector Address Offset	Form of Detection	Selectable Interrupt Request Destination		sstb Return	sacs Return	IER	IPR
						CPU	DTC				
High	SCI2	ERI2	222	0378h	Level	√	×	×	×	IER1B.IEN6	IPR82
		RXI2	223	037Ch	Edge	√	√	×	×	IER1B.IEN7	
		TXI2	224	0380h	Edge	√	√	×	×	IER1C.IEN0	
		TEI2	225	0384h	Level	√	×	×	×	IER1C.IEN1	
	—	Reserved	226	0388h	—	×	×	×	×	IER1C.IEN2	—
		Reserved	227	038Ch	—	×	×	×	×	IER1C.IEN3	—
		Reserved	228	0390h	—	×	×	×	×	IER1C.IEN4	—
		Reserved	229	0394h	—	×	×	×	×	IER1C.IEN5	—
		Reserved	230	0398h	—	×	×	×	×	IER1C.IEN6	—
		Reserved	231	039Ch	—	×	×	×	×	IER1C.IEN7	—
		Reserved	232	03A0h	—	×	×	×	×	IER1D.IEN0	—
		Reserved	233	03A4h	—	×	×	×	×	IER1D.IEN1	—
		Reserved	234	03A8h	—	×	×	×	×	IER1D.IEN2	—
		Reserved	235	03ACh	—	×	×	×	×	IER1D.IEN3	—
		Reserved	236	03B0h	—	×	×	×	×	IER1D.IEN4	—
		Reserved	237	03B4h	—	×	×	×	×	IER1D.IEN5	—
		Reserved	238	03B8h	—	×	×	×	×	IER1D.IEN6	—
		Reserved	239	03BCh	—	×	×	×	×	IER1D.IEN7	—
		Reserved	240	03C0h	—	×	×	×	×	IER1E.IEN0	—
		Reserved	241	03C4h	—	×	×	×	×	IER1E.IEN1	—
		Reserved	242	03C8h	—	×	×	×	×	IER1E.IEN2	—
		Reserved	243	03CCh	—	×	×	×	×	IER1E.IEN3	—
		Reserved	244	03D0h	—	×	×	×	×	IER1E.IEN4	—
		Reserved	245	03D4h	—	×	×	×	×	IER1E.IEN5	—
	RIIC0	ICEEI0	246	03D8h	Level	√	×	×	×	IER1E.IEN6	IPR88
		ICRXI0	247	03DCh	Edge	√	√	×	×	IER1E.IEN7	IPR89
		ICTXI0	248	03E0h	Edge	√	√	×	×	IER1F.IEN0	IPR8A
		ICTEI0	249	03E4h	Level	√	×	×	×	IER1F.IEN1	IPR8B
	—	Reserved	250	03E8h	—	×	×	×	×	IER1F.IEN2	—
		Reserved	251	03ECh	—	×	×	×	×	IER1F.IEN3	—
		Reserved	252	03F0h	—	×	×	×	×	IER1F.IEN4	—
		Reserved	253	03F4h	—	×	×	×	×	IER1F.IEN5	—
	LIN0	LIN0	254	03F8h	Edge	√	×	×	×	IER1F.IEN6	IPR90
Low	—	Reserved	255	03FCh	—	×	×	×	×	IER1F.IEN7	—

√: Selectable ×: Not selectable

11.3.2 Fast Interrupt Vector

The address of the entry in the interrupt vector table that corresponds to the vector number of the fast interrupt is specified by the fast interrupt vector register (FINTV) of the CPU.

11.3.3 Non-maskable Interrupt Vector

The vector for the NMI pin interrupt is at FFFF FFF8h.

11.4 Interrupt Operation

The interrupt controller performs the following processing.

- Detecting interrupts
- Enabling and disabling interrupts
- Selecting interrupt request destinations (CPU interrupt, DTC activation)
- Determining priority

11.4.1 Detecting Interrupts

Interrupt requests are detected in either of two ways: the detection of edges of the interrupt signal or the detection of a level of the interrupt signal.
Edge detection or level detection is selected for the IRQn pins (n = 7 to 0) as interrupt sources by the setting of the IRQMD[1:0] bits in IRQCRn.
For interrupts from peripheral modules, either edge detection or level detection is determined per interrupt source.
For the correspondence between interrupt sources and methods of detection, see Table 11.4, Interrupt Vector Table.

11.4.1.1 Operation of Status Flags for Edge-Detected Interrupts

Figure 11.2 shows the operation of the IR flag in IRi in the case of edge detection of an interrupt from a peripheral module or on an external pin.
The IR flag in IRi is set to 1 immediately after the transition of the interrupt signal due to generation of the interrupt. If the CPU is the request destination for the interrupt, the IR flag in IRi is automatically cleared on acceptance of the interrupt. If the DTC is the request destination for the interrupt, the timing of the IR flag clear depends on the DTC transfer setting and number of times of transfer. For details, see Table 11.5. Therefore, the software does not have to clear the IR flag in IRi.
Interrupt signals corresponding to interrupt vectors with numbers from 64 to 71 have different timing from the other interrupts. When an interrupt with a vector number from 64 to 71 is used as an IRQ-pin interrupt, the internal delay from input on the pin is extended by two cycles of PCLK.

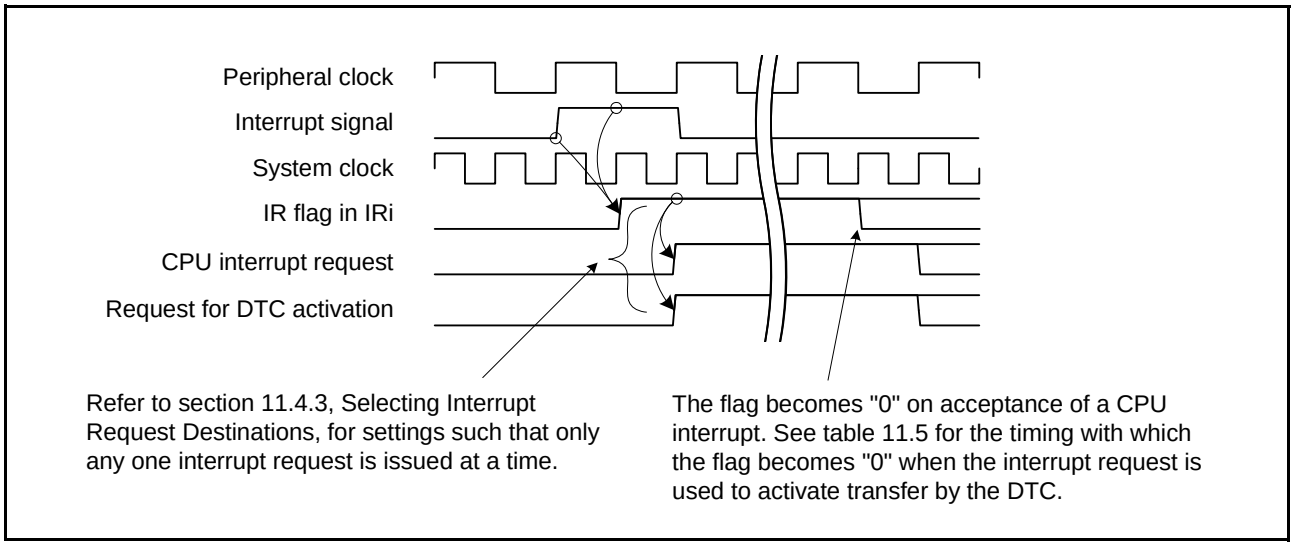


Figure 11.2 Operation of the IRi.IR Flag in the Case of Edge Detection

If the corresponding IR flag in IRi has already been set to 1 by a generated interrupt request, the generation of a further interrupt request will be ignored.
In addition to the IRi.IR flag, all the interrupts of the GPT, MTU3, and LIN, and the CMPI interrupt of the S12ADA have the status flags which are not automatically cleared to 0 depending on several sources. Therefore, if a further interrupt is generated while the corresponding flag is 1, the interrupt will be ignored. To enable the acceptance of an interrupt, the flag of the interrupt generation source should be 0. For details on the target status flag, refer to the section of each peripheral module.
If the IR flag has been cleared to 0, it will be set again by the generation of a further interrupt request. The timing for re-setting of the IR flag is shown in Figure 11.3.
When communication functions (SCI, RIIC, RSPI) and DTC are combined, an interrupt request is ignored and transfer requests may be lost in some cases. For details, see section 11.7, Usage Notes.

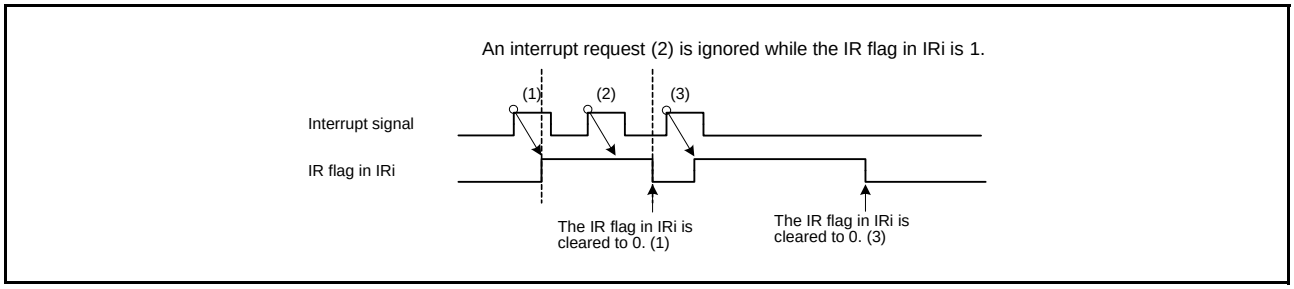


Figure 11.3 Timing for Re-setting of the IRi.IR Flag

If a source for interrupt generation is disabled over the period where the IR flag in the corresponding IRi is set (output of the interrupt request by the relevant peripheral module is disabled by clearing the interrupt enable bit), the IR flag is not affected but retains its state. Figure 11.4 shows operation when the source for interrupt generation has been disabled.

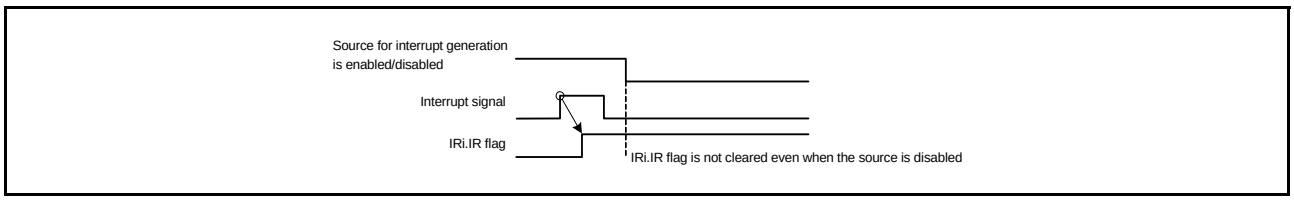


Figure 11.4 Relation between the IRi.IR Flag and Disabling of the Corresponding Interrupt Source

11.4.1.2 Operation of Status Flags for Level-Detected Interrupts

Figure 11.5 shows the operation of the interrupt status flag (IR flag) in IRi in the case of level detection of an interrupt from a peripheral module or an external pin.

The IR flag in IRi remains set as long as the interrupt signal is asserted. To clear the IR flag in IRi, withdraw the interrupt request at the source of the interrupt.

Confirm that the interrupt request flag in the source generating the interrupt has actually been cleared before stopping the interrupt handler. Figure 11.6 shows the level-detected interrupt handling procedure.

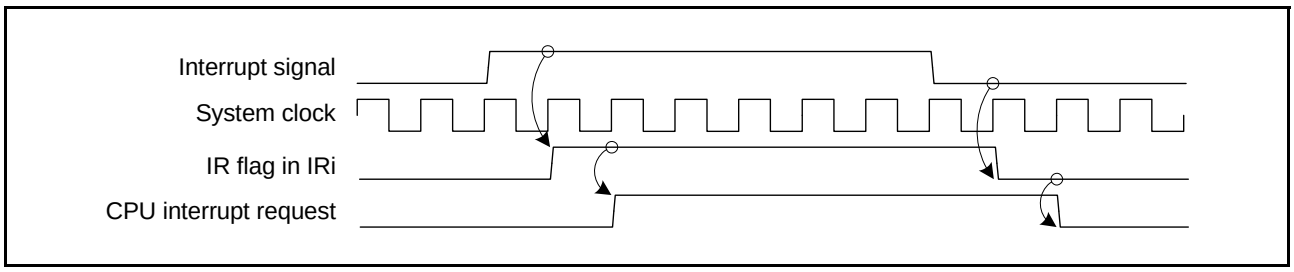


Figure 11.5 Operation of the IRi.IR Flag in the Case of a Level-Detected Interrupt

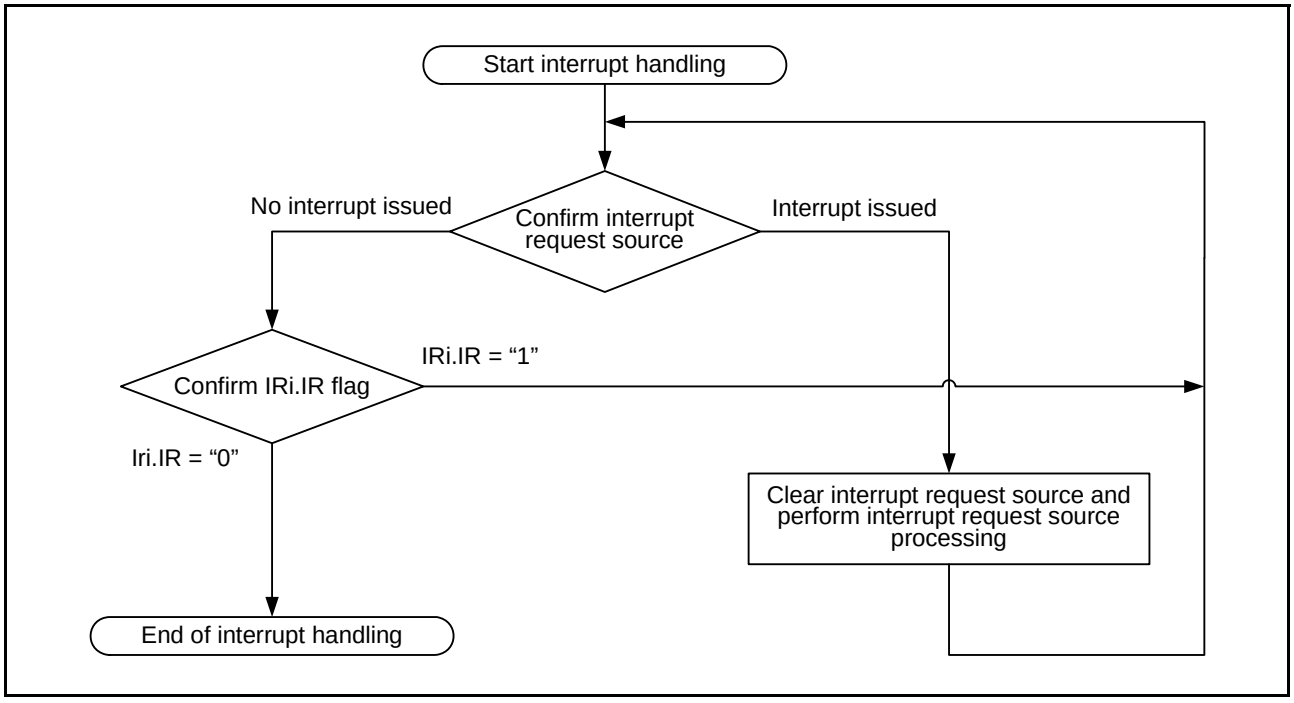


Figure 11.6 Level-Detected Interrupt Handling Procedure

11.4.2 Enabling and Disabling Interrupt Sources

Enabling requests from a given interrupt source requires the following settings.

1. In the case of interrupt requests from peripheral modules, setting the interrupt enable bit for the peripheral module to permit the output of interrupt requests from the source
2. Enabling of the interrupt by the IENj bit in IERm

When an interrupt request is generated by a source for interrupt generation for which interrupt output has been enabled, the IR flag in the corresponding IRi register is set.
Setting the IENj bit in IERm to enable an interrupt request causes a set IR flag in the IRi register corresponding to that interrupt request to be output to the interrupt request destination. Furthermore, if the IENj bit in IERm has been used to disable the interrupt request, the state of the interrupt request for which the IR flag in the corresponding IRi register has been set is held.
The IR flag in IRi is not affected by the IENj bit in IERm.

11.4.3 Selecting Interrupt Request Destinations

Possible settings for the request destination of each interrupt are fixed. That is, settings for request destination other than those indicated in Table 11.4, Interrupt Vector Table, are not possible. Do not make an interrupt request destination setting that is not indicated by a √ in Table 11.4.
If the DTC is selected as the request destination for an IRQ pin, be sure to set the IRQMD[1:0] bits in IRQCRn for that interrupt to select edge detection.
The following describes how to specify the interrupt request destination.

(1) DTC Activation

Make the following settings while the IERm.IENj bit is 0.

1. Set the DTC activation enable bit (DTCERn.DTCE) in the DTC activation enabler register for the required source to 1.
2. Set the DTC module activation bit (DTCST.DTCST) to 1.

After the above settings, set the IERm.IENj bit to 1.
For the DTC setting, see section 14.5, DTC Setting Procedure.

(2) CPU Interrupt Request

If the interrupt request destination is the DTC, the interrupt request is sent to the CPU. Set the IERm.IENj bit to 1 while the DTC activation setting described above is made.

Table 11.5 covers operation when the DTC is the request destination.

Table 11.5 Operation at the Time of DTC Activation

Interrupt Request Destination	DTC.MRB.DISEL	Remaining Number of Transfer Operations	Operation per Request	IRi.IR *1*3	Interrupt Request Destination after Transfer
DTC*2	1	≠0	DTC transfer → CPU interrupt	Cleared on interrupt acceptance by the CPU	DTC
		=0	DTC transfer → CPU interrupt	Cleared on interrupt acceptance by the CPU	The DTCE bit in DTCR is cleared and the CPU becomes the destination.
	0	≠0	DTC transfer	Cleared on the start of DTC data transfer after DTC transfer information has been read	DTC
		=0	DTC transfer → CPU interrupt	Cleared on interrupt acceptance by the CPU	The DTCE bit in DTCERn is cleared and the CPU becomes the destination.

Note 1. An interrupt request (DTC activation request) that is regenerated while the IR flag in IRi is still set will be ignored.
Note 2. For the chain transfer, DTC transfer is continued until the last chain transfer completes. Each of operations of CPU interrupt, IR flag clear, and interrupt request destination after transfer for the last chain transfer, depends on the setting of DISEL bit for the last chain transfer and the remaining specified number of transfers.
Note 3. If a re-generated interrupt request (DTC activation request) is ignored while the IRi.IR flag is set, some problems may occur to the communication functions (SCI, RIIC, RSPI). Therefore, such communication functions should be used under the condition where the interrupt request is not ignored or with taking the preventive measures through software. For details, see section 11.7, Usage Notes.

The request destination for an interrupt should be changed while the IERm.IENj bit is 0.
To change the interrupt request destination or the DTC transfer information while the transfer is not completed (DTCERn.DTCE bit is not cleared) after the settings described in (1) DTC Activation are made, use the following procedure.

1. Clear the IENj bits in IERm for both the source to be replaced and the source that will be the new trigger for activation to 0.
2. Check the state of transfer by the DTC. If transfer is in progress, wait for its completion.
3. Make the settings described in (1) DTC Activation.

11.4.4 Determining Priority

Interrupt priority is determined for each interrupt request destination.
The priority for each interrupt request destination is determined as follows.

(1) Determining Priority when the CPU is the Request Destination of the Interrupt Signal

The source that has been specified as the fast interrupt (described below) has the highest priority. After that, an interrupt source with a larger value of the interrupt priority level select bits (IPR[3:0]) in IPRm takes precedence. If interrupts with the same priority level are generated by multiple sources, the source with the smallest vector number takes precedence.

(2) Determining Priority when the DTC is the Request Destination of the Interrupt Signal

The IPR[3:0] bits in IPRm have no effect. An interrupt source with a smaller vector number takes precedence.

11.4.5 Fast Interrupt

The fast interrupt is a facility for faster interrupt processing by the CPU, so is only effective for an interrupt request being conveyed to the CPU. That is, the fast interrupt setting has no effect on transfer requests for the DTC.
The fast interrupt is set up by specifying the vector number of an interrupt source in the FVCT[7:0] bits of FIR and enabling the fast interrupt by setting the FIEN bit in FIR to 1. When the given source generates an interrupt, the interrupt is output to the CPU for handling as the fast interrupt.
The interrupt source selected for the fast interrupt has the highest priority regardless of the setting of the IPR[3:0] bits in IPRm.
For details on the fast interrupt, see section 10, Exceptions.

11.4.6 External Pin Interrupts

The procedure for using the signal on an external pin as an interrupt is given below.

1. Clear the IENj bit in IERm (IERm.IENj = 0).
2. Set and check the settings for the I/O port pin.
3. Set the method of detection for the interrupt in the IRQMD[1:0] bits of IRQCRn.
4. Clear the IR flag in the corresponding IRi register to 0 (if edge detection is in use).
5. If the interrupt is to be used for DTC activation, set the DTCE bit in DTCERn. The interrupt will be a CPU interrupt if these settings are not made.
6. Set the IENj bit in IERm (IERm.IENj = 1).

11.5 Non-Maskable Interrupt Operation

The three kinds of non-maskable interrupt are produced by an interrupt signal on the NMI pin, voltage monitoring, and detection of stoppage of oscillation. A non-maskable interrupt can only act as an interrupt for the CPU and is not capable of activating the DTC. Non-maskable interrupts take precedence over all other interrupts, including the fast interrupt.
A non-maskable interrupt request is accepted regardless of the settings of the I bit (interrupt enable bit) and the IPL[3:0] bits (processor interrupt priority level) in the PSW of the CPU. The presence or absence of non-maskable interrupt requests can be confirmed by checking the value of the non-maskable interrupt status register (NMISR). Confirm that all bits of the NMISR have returned to 0 from within the routine for the non-maskable interrupt. Non-maskable interrupts are disabled by default.
If a system is to use non-maskable interrupts, follow the procedure below at the beginning of program processing.

Non-Maskable Interrupt Usage Procedure:

1. Set the stack pointer (SP).
2. If the NMI pin is to be used, make the detection sense setting (the NMIMD bit in the NMICR).
3. If the NMI pin is to be used, clear the NMIST flag in the NMISR by writing 1 to the NMICLR bit in NMICLR.
4. Enable the non-maskable interrupt by writing 1 to the corresponding bit in the non-maskable interrupt enable register (NMIER).

After the NMIEN bit in NMIER is set to 1, subsequent write access to the NMIEN bit in NMIER is ignored. The non-maskable interrupt cannot be disabled. The non-maskable interrupt is disabled only by a reset.
For the flow of non-maskable interrupt processing, see section 10, Exceptions.
Writing 1 to the NMICLR.NMICLR bit clears the NMI pin status flag (NMISR.NMIST).
Writing 1 to NMICLR.OSTCLR bit clears the oscillation stop detection interrupt status flag (NMISR.OSTST).
For clearing the voltage-monitoring interrupt status flag (NMISR.LVDST), see section 7, Voltage Detection Circuit (LVD).
Do not issue a WAIT instruction while any bit in the NMISR is 1.

11.6 Return from Power-Down States

The interrupt sources that can be used to return operation from sleep mode, all-module clock stop mode, or software standby mode are shown in Table 11.4, Interrupt Vector Table.
For details, refer to section 9, Low Power Consumption. The following describes how to use an interrupt to return operation from each power-down mode.

11.6.1 Return from Sleep Mode

If the interrupt controller is to return operation from sleep mode in response to an interrupt or non-maskable interrupt, make the following settings for the interrupt.

- Interrupts

1. Select the CPU as the interrupt request destination.
2. Use the IENj bit in IERm to enable the given interrupt request.
3. Set an interrupt priority level higher than that set by the IPL[3:0] bits in the PSW of CPU.

- Non-maskable interrupts

Use the NMIER register to enable the given interrupt request.

11.6.2 Return from All-Module Clock Stop Mode

If the interrupt controller is to return operation from all-module clock stop mode in response to an interrupt or non-maskable interrupt, make the following settings for the interrupt.

- Interrupts

1. Select the interrupt source that enables the return from the all-module clock stop mode.
2. Select the CPU as the interrupt request destination.
3. Use the IENj bit in IERm to enable the given interrupt request.
4. Set an interrupt priority level higher than that set by the IPL[3:0] bits in the PSW of CPU.

- Non-maskable interrupts

Use the NMIER register to enable the given interrupt request.

11.6.3 Return from Software Standby Mode

The interrupt controller can return operation from a non-maskable interrupt or an interrupt that enables the return from the software standby mode.
The conditions for the return are listed below.

- Interrupts

1. Select the interrupt source that enables the return from the software standby mode.
2. Select the CPU as the interrupt request destination.
3. Use the IENj bit in IERm to enable the given interrupt request.
4. Set an interrupt priority level higher than that set by the IPL[3:0] bits in the PSW of CPU.

To use the interrupt source specified as a fast interrupt to return from software standby mode, the interrupt priority level (IPRm) should be set higher than the level set by IPL in the PSW of the CPU in addition to setting the fast interrupt set register (FIR).
Interrupt requests through the IRQ pins that do not satisfy the above conditions are not detected while the clock is stopped in software standby mode.

- Non-maskable interrupts

Use the NMIER register to enable the given interrupt request.

11.7 Usage Notes

11.7.1 Notes on Communication Using DTC Transfer

In the RX62T Groups, be careful of using the communication functions using DTC transfer. When an interrupt request is generated while the IRi.IR flag is set to 1, re-generated interrupt request is ignored. If the DTC is the request destination for the interrupt, the timing of the IR flag clear depends on the DTC transfer setting and number of times of transfer. Therefore, a transfer request may be lost depending on the combinations of the settings. When communication functions (SCI, RIIC, RSPI) and DTC are combined, consider the following notes.

(1) Conditions of Transfer Request Loss during Communication using DTC Transfer

Table 11.6 shows the combinations of the DTC function which require special care.

Table 11.6 Combinations of the DTC Function which Require Special Care

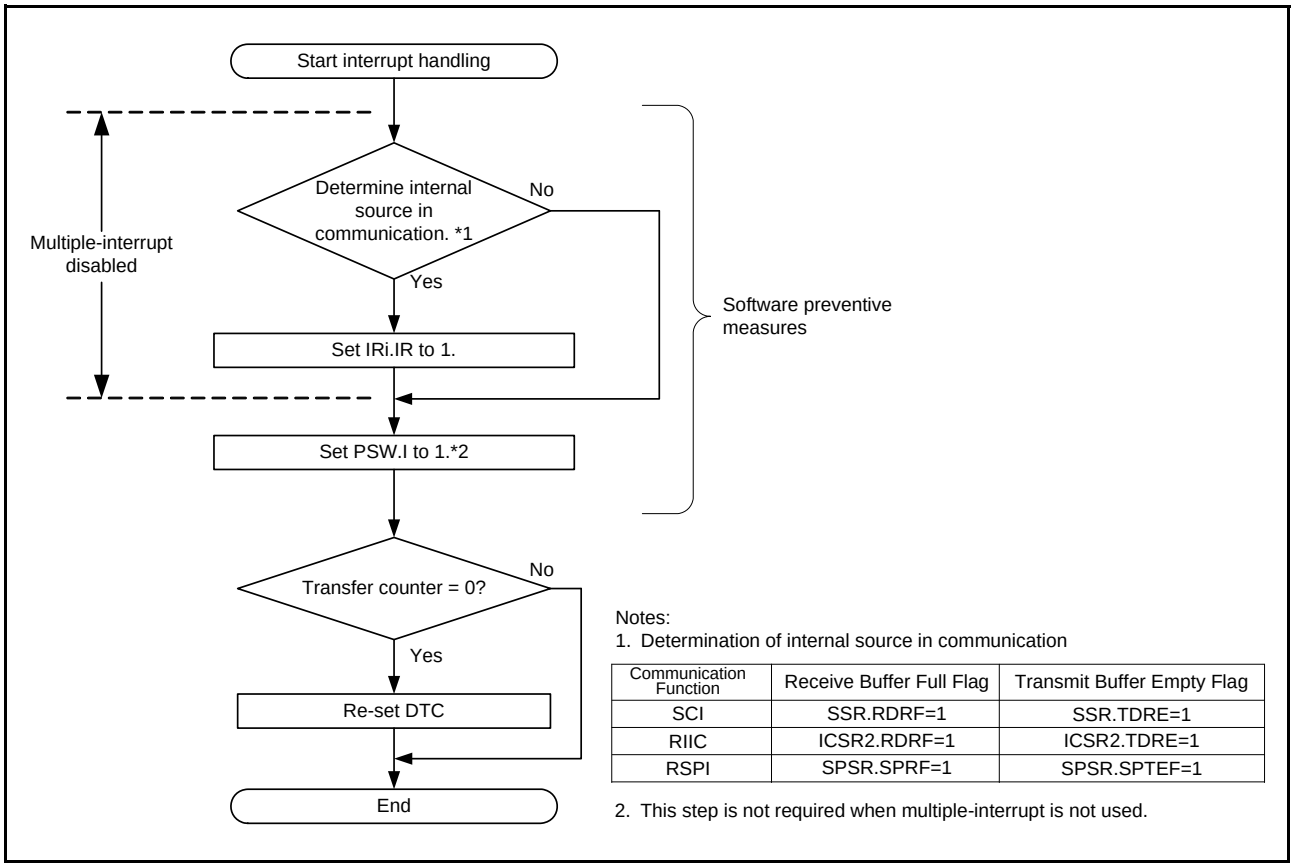
	Chain Transfer Used or Not Used	Communication Interrupts to CPU Issued or Not Issued after Each Transfer*1 (DISEL Setting)	Possibility of Problem Generation
DTC	Chain transfer not used	DISEL = 0 (Transfer counter value > 0)	Impossible
		DISEL = 0 (Transfer counter value = 0 at the last transfer)	Impossible*2
		DISEL = 1	Possible
	Chain transfer used	DISEL = 0 (Transfer counter value > 0 and communication register is accessed at the end of the chain)	Impossible
		DISEL = 0 (Transfer counter value = 0 at the last transfer and communication register is accessed at the end of the chain)	Impossible*2
		DISEL = 1	Possible

Note 1. Communication interrupts include: transmit data empty and receive data full interrupts from SCI, RIIC, and RSPI.
Note 2. If the IRi.IR flag is cleared too late for the transfer request of the next packet to be transmitted/received, the same problem may occur as with the case in DISEL = 1.

(2) Notes on Communication using DTC Transfer when DISEL = 1

The IR flag is automatically cleared on interrupt acceptance by the CPU after data transfer (DTC operation). A transfer request will be lost if the next transfer request is issued before the IR flag is automatically cleared. When DISEL is set to 1, a CPU interrupt is always generated: therefore, take the preventive measures through software shown below.

(3) Flowchart of Software Preventive Measures (for SCI, RIIC, RSPI)



Notes:
1. Determination of internal source in communication

Communication Function	Receive Buffer Full Flag	Transmit Buffer Empty Flag
SCI	SSR.RDRF=1	SSR.TDRE=1
RIIC	ICSR2.RDRF=1	ICSR2.TDRE=1
RSPI	SPSR.SPRF=1	SPSR.SPTEF=1

2. This step is not required when multiple-interrupt is not used.

Figure 11.7 Flowchart of Software Preventive Measures (for SCI, RIIC, RSPI)

12. Buses

12.1 Overview

Figure 12.1 lists the bus specifications, Table 12.1 shows the bus configuration, and Table 12.2 shows the addresses assigned for each bus.

Table 12.1 Bus Specifications

Bus Type		Description
CPU bus	Instruction bus	• Connected to the CPU (for instructions) • Connected to on-chip memory (on-chip RAM, on-chip ROM) • Operates in synchronization with the system clock (ICLK)
	Operand bus	• Connected to the CPU (for operands) • Connected to on-chip memory (on-chip RAM, on-chip ROM) • Operates in synchronization with the system clock (ICLK)
Memory bus	Memory bus 1	• Connected to on-chip RAM
	Memory bus 2	• Connected to on-chip ROM
Internal main bus	Internal main bus 1	• Connected to the CPU • Operates in synchronization with the system clock (ICLK)
	Internal main bus 2	• Connected to the DTC • Connected to on-chip memory (on-chip RAM, on-chip ROM) • Operates in synchronization with the system clock (ICLK)
Internal peripheral bus	Internal peripheral bus 1	• Connected to peripheral modules(such as a bus error monitoring section and an interrupt) • Operates in synchronization with the system clock (ICLK)
	Internal peripheral bus 2	• Connected to peripheral modules(such as WDT, CMT, CRC, and SCI) • Operates in synchronization with the peripheral-module clock (PCLK)
	Internal peripheral bus 4	• Connected to peripheral modules (MTU3 and GPT) • Operates in synchronization with the system clock (ICLK)
	Internal peripheral bus 6	• Connected to on-chip ROM (for programming and erasure) and data-flash memory • Operates in synchronization with the peripheral-module clock (PCLK)

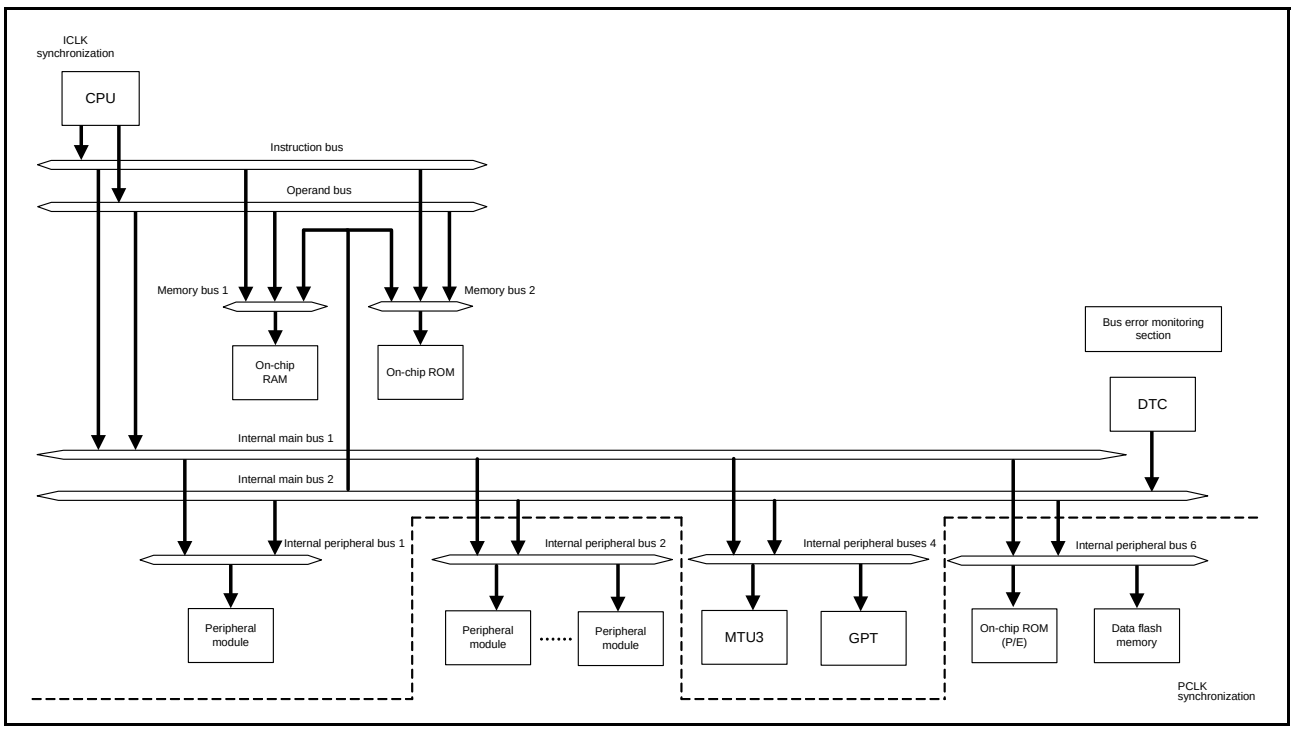


Figure 12.1 Bus Configuration

Table 12.2 Addresses Assigned for Each Bus

Address	Type of Bus	Area
0000 0000h to 0000 3FFFh	Memory bus 1	On-chip RAM
0000 4000h to 0007 FFFFh		Reserved area
0008 0000h to 0008 7FFFh	Internal peripheral bus 1	Peripheral I/O registers
0008 8000h to 0009 FFFFh	Internal peripheral bus 2	
000A 0000h to 000B FFFFh	Reserved area	Reserved area
000C 0000h to 000D FFFFh	Internal peripheral bus 4	Peripheral I/O registers
000E 0000h to 000F FFFFh	Reserved area	Reserved area
0010 0000h to 0011 FFFFh	Internal peripheral bus 6	Data flash memory
0012 0000h to 007F 7FFFh		Reserved area
007F 8000h to 007F 9FFFh		FCU RAM
007F A000h to 007F BFFFh		Reserved area
007F C000h to 007F C4FFh		Peripheral I/O registers
007F C500h to 007F FBFFh		Reserved area
007F FC00h to 007F FFFFh		Peripheral I/O registers
0080 0000h to 00DF FFFFh		Reserved area
00E0 0000h to 00FF FFFFh		On-chip ROM(dedicated area for writing)
0100 0000h to 7FFF FFFFh	Reserved area	Reserved area
8000 0000h to FFFF FFFFh	Memory bus 2	On-chip ROM (dedicated area for reading)

12.2 Description of Buses

12.2.1 CPU Buses

The CPU buses consist of the instruction and operand buses, which are connected to internal main bus 1. As the names suggest, the instruction bus is used to fetch instructions for the CPU, while the operand bus is used for operand access. Connection of the instruction and operand buses to on-chip RAM and on-chip ROM provides the CPU with direct access to these areas, i.e. access is not via internal main bus 1. However, only reading is possible in direct access to on-chip ROM by the CPU; programming and erasure are handled via an internal peripheral bus.
Bus requests for instruction fetching and operand access, that are not for the on-chip RAM or on-chip ROM, are arbitrated through internal main bus 1. The order of priority is operand access then instruction fetching.
If instruction fetching and operand access are requested for different buses (memory bus 1, memory bus 2, and internal main bus 1), the bus-access operations can proceed simultaneously. For example, parallel access to on-chip ROM and on-chip RAM or to on-chip ROM is possible.

12.2.2 Memory Buses

The memory buses consist of memory bus 1 and memory bus 2. On-chip RAM is connected to memory bus 1 and on-chip ROM is connected to memory bus 2. Requests for bus mastership from the CPU buses (instruction fetching and operand) and internal main bus 2 are arbitrated through memory buses 1 and 2.
The order of priority is internal main bus 2 then CPU bus (operand then instruction fetching).

12.2.3 Internal Main Buses

The internal main buses consist of a bus for use by the CPU (internal main bus 1) and a bus for use by the other bus-master modules, i.e. the DTC (internal main bus 2).
Bus requests for instruction fetching and operand access, that are not for the on-chip RAM or on-chip ROM, are arbitrated through internal main bus 1. The order of priority is operand then instruction fetching.
If the CPU and another bus master are requesting access to different buses (on-chip memory, internal peripheral buses 1 2, 4, and 6), the respective bus-access operations can proceed simultaneously.
The order of priority is internal main bus 2 then internal main bus 1. However, when the CPU executes the XCHG instruction, requests for bus access from masters other than the CPU are not accepted until data transfer for the XCHG instruction is completed. Furthermore, requests for bus access from masters other than the DTC are not accepted during reading and writing-back of transfer control information for the DTC.

Table 12.3 Order of Priority for Bus Masters

Priority	Bus Master
High	DTC
↑	CPU
Low	

12.2.4 Internal Peripheral Buses

Connection of peripheral modules to the internal peripheral buses is as described in Table 12.4.

Table 12.4 Connection of Peripheral Modules to the Internal Peripheral Buses

Type of Bus	Peripheral Modules
Internal peripheral bus 1	• Interrupt controller • Bus error monitoring section
Internal peripheral bus 2	• Peripheral modules other than those connected to internal peripheral buses 1 and 4 • Data flash memory
Internal peripheral bus 4	• MTU3 and GPT
Internal peripheral bus 6	• On-chip ROM (P/E)/Data flash memory

Requests for bus mastership from the CPU (internal main bus 1) and other bus masters (internal main bus 2) are arbitrated through internal peripheral buses 1, 2, 4, and 6.
The order of priority is internal main bus 2 then internal main bus 1.

12.2.5 Parallel Operation

Parallel operation is possible when different bus-master modules are requesting access to different slave modules. For example, if the CPU is fetching an instruction from on-chip ROM and accessing an operand from on-chip RAM, the DTC is able to handle transfer between a peripheral bus and a peripheral bus at the same time.
An example of parallel operations is given in Figure 12.2. In this example, the CPU is able to employ the instruction and operand buses for simultaneous access to on-chip ROM and on-chip RAM, respectively. Furthermore, the DTC simultaneously employs internal main bus 2 for access to a peripheral bus during access to on-chip RAM and ROM by the CPU.

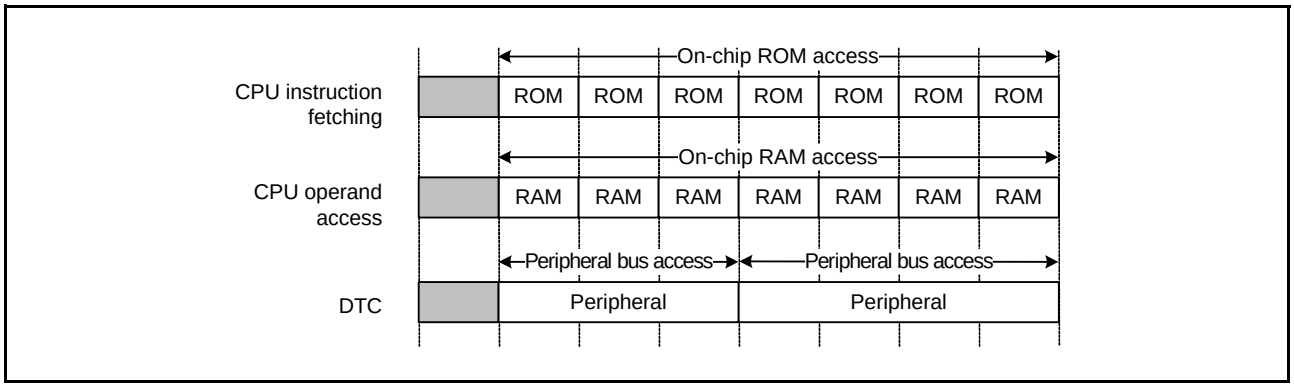


Figure 12.2 Example of Parallel Operations

12.2.6 Restrictions

(1) Restrictions in relation to RMPA and string-manipulation instructions

The allocation of data to be handled by RMPA or string-manipulation instructions to I/O registers is prohibited, and operation is not guaranteed if this restriction is not observed.

12.3 Register Descriptions

Table 12.5 lists the registers of the bus error monitoring section.

Table 12.5 Registers of the Bus Error Monitoring Section

Register Name	Symbol	Value after Reset	Address	Access Size
Bus error status clear register	BERCLR	00h	0008 1300h	8
Bus error monitoring enable register	BEREN	00h	0008 1304h	8
Bus error status register 1	BERSR1	00h	0008 1308h	8
Bus error status register 2	BERSR2	0000h	0008 130Ah	16

12.3.1 Bus Error Status Clear Register (BERCLR)

Address: 0008 1300h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	STSCLR
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	STSCLR	Status Clear	0: Invalid 1: Bus error status register cleared	R/(W)*1
b7 to b1	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W

Note 1. Only writing 1 is effective; i.e. writing 0 has no effect.

STSCLR Bit (Status Clear)

Writing 1 to this bit clears the bus-error status registers 1and 2 (BERSR1 and BERSR2).

12.3.2 Bus Error Monitoring Enable Register (BEREN)

Address: 0008 1304h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	IGAEN
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	IGAEN	Illegal Address Access Detection Enable	0: Illegal address access detection is disabled. 1: Illegal address access detection is enabled.	R/W
b7 to b1	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W

IGAEN Bit (Illegal Address Access Detection Enable)

This bit enables or disables detection of access to illegal addresses.

12.3.3 Bus Error Status Register 1 (BERSR1)

Address: 0008 1308h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	MST[2:0]			—	—	—	IA
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	IA	Illegal Address Access	0: Illegal address access not made 1: Illegal address access made	R
b3 to b1	—	Reserved	These bits are always read as 0. Writing to these bits has no effect.	R
b6 to b4	MST[2:0]	Bus Master Code	b6 b4 0 0 0: CPU 0 0 1: Setting prohibited 0 1 0: Setting prohibited 0 1 1: DTC 1 0 0: Setting prohibited 1 0 1: Setting prohibited 1 1 0: Setting prohibited 1 1 1: Setting prohibited	R
b7	—	Reserved	This bit is always read as 0. Writing to this bit has no effect.	R

BERSR1 indicates the bus error generation status. It indicates whether an illegal address access was made (IA bit), or which bus master accessed the bus (MST[2:0] bits)

IA Bit (Illegal Address Access Flag)

This bit indicates whether an illegal address access was made.

MST[2:0] Bits (Bus Master Code)

These bits indicate the bus master that accessed a bus when a bus error occurred.

12.3.4 Bus Error Status Register 2 (BERSR2)

Address: 0008 130Ah

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	ADDR[12:0]													—	—	—
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b2 to b0	—	Reserved	These bits are always read as 0. Writing to these bits has no effect.	R
b15 to b3	ADDR[12:0]	Bus Error Occurrence Address	The upper 13 bits of an address that was accessed when a bus error occurred (in units of 512 Kbytes).	R

BERSR2 indicates the upper 13 bits of an address having caused a bus error.

ADDR[12:0] Bits (Bus Error Occurrence Address)

These bits indicate the upper 13 bits of an address having caused a bus error.

12.4 Bus Error Monitoring Section

The bus-error monitoring section monitors the individual areas for bus errors. When a bus error is occurred, this section indicates it to the bus master. Bus error has an illegal address access, which is the detection of illegal access to an area.

12.4.1 Types of Bus Error

Bus error has an illegal address access, which is the detection of illegal access to an area.

12.4.1.1 Illegal Address Access

When the illegal address access detection enable bit (IGAEN) in the bus error monitoring enable register (BEREN) is set to 1, access of the following types leads to illegal address access errors.

- Access to areas of external space for which operation has been disabled

The address ranges where access will lead to illegal address access errors are indicated in Table 12.6.

12.4.2 Operations When a Bus Error Occurs

When a bus error occurs, the error is indicated to the CPU. Operation is not guaranteed when a bus error occurs.

- Bus error indication to the CPU
  An interrupt is generated. The IEN register in the ICU can specify whether to generate an interrupt in the case of a bus error.

12.4.3 Conditions Leading to Bus Errors

Table 12.6 lists the types of bus errors for each area in the respective address space.

If an illegal address access error is detected when no bus error has occurred (bus error status register n (BERSRn; n = 1 or 2) is cleared), the detected error is reflected on the BERSRn. Once a bus error occurs, no subsequent bus errors are reflected on the register unless the register is cleared.

If bus errors are simultaneously caused by two bus masters, error information of only one bus master is reflected. Once a bus error occurs, the status is retained until BERSRn register is cleared.

Table 12.6 Types of Bus Errors

		Type of Error
Address	**Type of Area**	**Illegal Address Access**
0000 0000h to 0000 3FFFh	On-chip RAM*1	—
0000 4000h to 0007 FFFFh	Reserved area	
0008 0000h to 0009 0FFFh	Peripheral I/O registers	—
0009 1000h to 0009 3FFFh		√
0009 4000h to 0009 41FFh		—
0009 4200h to 0009 FFFFh		√
000A 0000h to 000B FFFFh		√
000C 0000h to 000C 0FFFh		√
000C 1000h to 000C 27FFh		—
000C 2800h to 000D FFFFh		√
000E 0000h to 000F FFFFh	Reserved area	√
0010 0000h to 0011 FFFFh	Data flash*1	—
0012 0000h to 007F 7FFFh	Reserved area	√
007F 8000h to 007F 9FFFh	FCU RAM	—
007F A000h to 007F BFFFh	Reserved area	√
007F C000h to 007F C4FFh	Peripheral I/O registers	—
007F C500h to 007F FBFFh	Reserved area	√
007F FC00h to 007F FFFFh	Peripheral I/O registers	—
0080 0000h to 00DF FFFFh	Reserved area	—
00E0 0000h to 00FF FFFFh	On-chip ROM*1 (dedicated area for writing)	—
0100 0000h to 7FFF FFFFh	Reserved area	√
8000 0000h to FFFF FFFFh	On-chip ROM* (dedicated area for reading)	—

— : A bus error is not produced.

√ : A bus error is produced.

Note 1. Amounts of on-chip RAM, data-flash memory, and on-chip ROM vary with the product. For the specifications of a given device, refer to section 30, RAM, section 31, ROM (Flash Memory for Code Storage), and section 32, Data Flash Memory (Flash Memory for Data Storage)

13. Memory-Protection Unit (MPU)

13.1 Overview

The RX CPU incorporates a memory-protection unit that checks the addresses of CPU access to the overall address space (0000 0000h to FFFF FFFFh).
Access-control information can be set for up to eight regions, and permission for access to each region is in accord with this information. The default response to the detection of access to a region where permission has not been set is the generation of a memory-protection error.
The supported access-control information for the individual regions consists of permission to read, permission to write, and permission to execute. This access-control information is effective when the processor mode of the CPU is user mode. Memory protection is not applied when the CPU is in supervisor mode.
Table 13.1 lists the specifications of the memory-protection unit, and Figure 13.1 shows a block diagram of the memory-protection unit.

Table 13.1 Specifications of Memory Protection

Specifictaions	Description
Region to be covered by memory protection and processor mode	0000 0000h to FFFF FFFFh (in user mode) No memory protection in supervisor mode
Number of regions	8
Page size (smallest unit of protection)	16 bytes
Specifying addresses of individual regions	Setting the page numbers where regions start and end
Setting to make memory protection effective or ineffective in individual regions	A V (valid) bit in each region-n end page number register (REPAGEn) makes the settings effective or ineffective for the corresponding region (n = 0 to 7).
Access-control information settings for individual regions	Instruction execution: Permission to execute Operand access: Permission to read, permission to write
Start of memory-protection operations	After the memory-protection unit has been enabled, access monitoring start-ing up with the transition to user mode.
Memory-protection error processing	Generation of access exceptions
Addresses where memory-protection errors are generated	Address in instruction execution: The PC value is preserved on the stack. Address in operand access: The address is stored in the data memory-protection error address register (MPDEA).
Determining the reasons for memory-protection errors	The memory-protection error status register (MPESTS) holds indicators of the reason.
Background region setting	Access-control information can be set for the background region (the whole address space).
Processing where regions overlap	The access-control information for access to an overlap between regions is the logical OR of the attributes for the given regions, and permission is given priority.

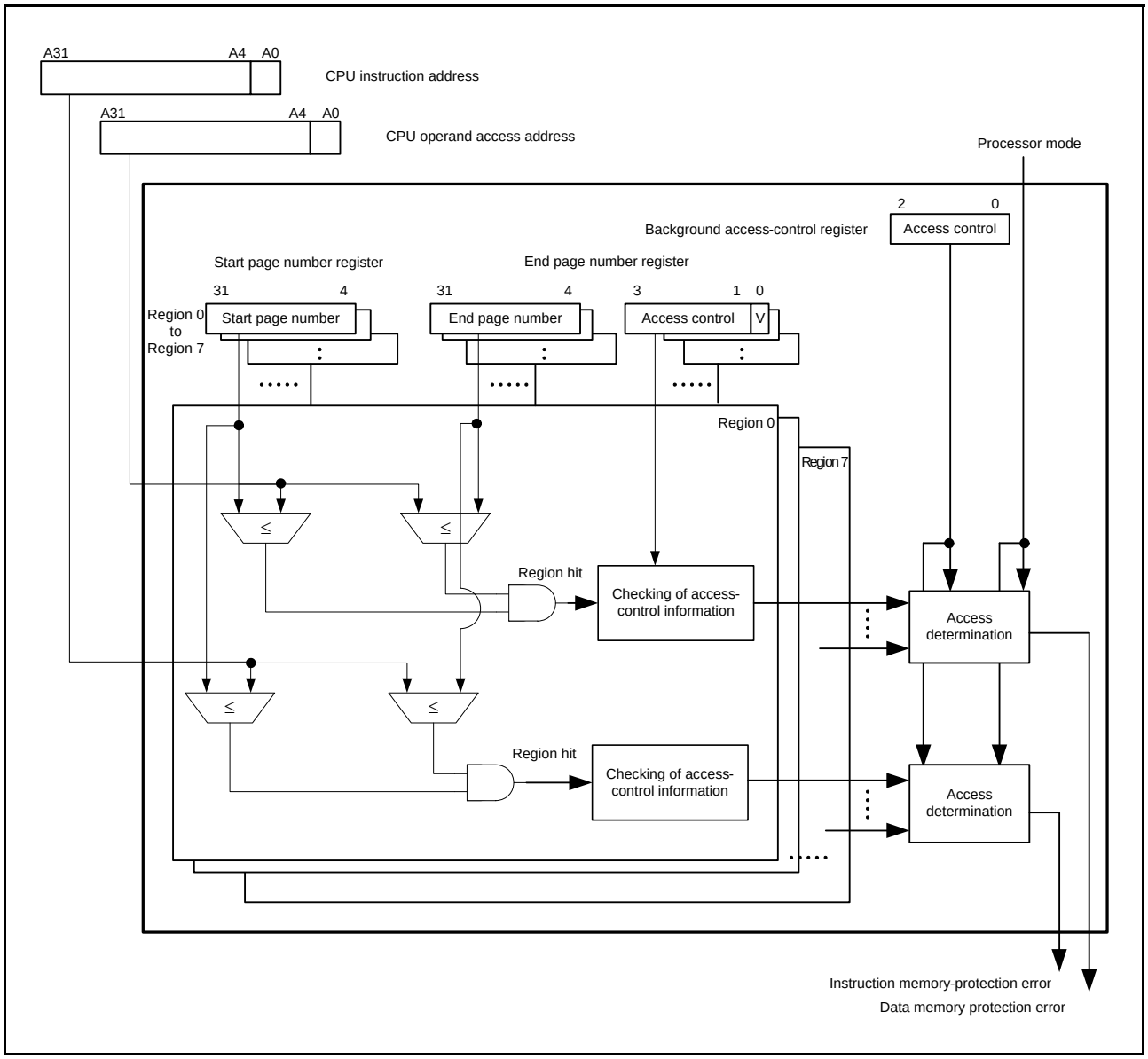


Figure 13.1 Block Diagram of the Memory-Protection Unit

13.1.1 Types of Access Control

There are three types of access control information: permission for instruction execution, permission to read operands, and permission to write operands. Violations of these types of access control are only detected when programs are running in user mode. Violations are not detected when programs are running in supervisor mode.

13.1.2 Regions for Access Control

Up to eight regions for access control are definable. Settings of the range of memory for each access-control region are made in the corresponding region-n start page number register (RSPAGEn) and region-n end page number register (REPAGEn), where n = 0 to 7.
The minimum unit for control of access is the "page", by which the address space is divided into 16-byte units. The 28 higher-order bits ([31:4]) of the address [31:0] bits correspond to the page number.
The REPAGEn register specifies the access-control information for each area and whether the area is enabled or not.

13.1.3 Background Region

“Background region” refers to the whole address space (0000 0000h to FFFF FFFFh). Access-control information for the background region is set in the background-region access-control register (MPBAC). In contrast to the access-control information for the eight individual regions, protection information for the background region is effective as long as memory protection is enabled (the MPEN bit in the MPEN register is 1).

13.1.4 Overlap between Regions

In cases of overlap between multiple regions, the access-control information becomes the logical OR of the access-control bits for the overlapping regions (including the background region), with permission given priority.

13.1.5 Instructions and Data that Span Regions

Operations in response to the detection of memory-protection errors when instructions or data span regions for which different access-control settings have been made are undefined. Ensure that instructions and data do not span regions for which different access-control settings have been made.

13.2 Register Descriptions

Table 13.2 lists the registers of the interrupt controller.

Table 13.2 Registers of the Memory-Protection Unit

Register Name	Symbol	Value after Reset	Address	Access Size
Region 0 start page-number register	RSPAGE0	xxxx xxx0h	0008 6400h	32
Region 0 end page-number register	REPAGE0	xxxx xxx0h	0008 6404h	32
Region 1 start page-number register	RSPAGE1	xxxx xxx0h	0008 6408h	32
Region 1 end page-number register	REPAGE1	xxxx xxx0h	0008 640Ch	32
Region 2 start page-number register	RSPAGE2	xxxx xxx0h	0008 6410h	32
Region 2 end page-number register	REPAGE2	xxxx xxx0h	0008 6414h	32
Region 3 start page-number register	RSPAGE3	xxxx xxx0h	0008 6418h	32
Region 3 end page-number register	REPAGE3	xxxx xxx0h	0008 641Ch	32
Region 4 start page-number register	RSPAGE4	xxxx xxx0h	0008 6420h	32
Region 4 end page-number register	REPAGE4	xxxx xxx0h	0008 6424h	32
Region 5 start page-number register	RSPAGE5	xxxx xxx0h	0008 6428h	32
Region 5 end page-number register	REPAGE5	xxxx xxx0h	0008 642Ch	32
Region 6 start page-number register	RSPAGE6	xxxx xxx0h	0008 6430h	32
Region 6 end page-number register	REPAGE6	xxxx xxx0h	0008 6434h	32
Region 7 start page-number register	RSPAGE7	xxxx xxx0h	0008 6438h	32
Region 7 end page-number register	REPAGE7	xxxx xxx0h	0008 643Ch	32
Memory-protection enable register	MPEN	0000 0000h	0008 6500h	32
Background access control register	MPBAC	0000 0000h	0008 6504h	32
Memory-protection error status-clearing register	MPECLR	0000 0000h	0008 6508h	32
Memory-protection error status register	MPESTS	0000 0000h	0008 650Ch	32
Data memory-protection error address register	MPDEA	xxxx xxxxh	0008 6514h	32
Region search address register	MPSA	xxxx xxxxh	0008 6520h	32
Region search operation register	MPOPS	0000h	0008 6524h	16
Region invalidation operation register	MPOPI	0000h	0008 6526h	16
Instruction-hit region register	MHITI	0000 0000h	0008 6528h	32
Data-hit region register	MHITD	0000 0000h	0008 652Ch	32

13.2.1 Region-n Start Page Number Register (RSPAGEn) (n = 0 to 7)

Addresses: RSPAGE0 0008 6400h, RSPAGE1 0008 6408h, RSPAGE2 0008 6410h, RSPAGE3 0008 6418h
RSPAGE4 0008 6420h, RSPAGE5 0008 6428h, RSPAGE6 0008 6430h, RSPAGE7 0008 6438h

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
	RSPN[27:0]															
Value after reset:	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	RSPN[27:0]												—	—	—	—
Value after reset:	x	x	x	x	x	x	x	x	x	x	x	x	0	0	0	0

x: Undefined

Bit	Symbol	Bit Name	Function	R/W
b3 to b0	—	Reserved	The read value is 0. The write value should always be 0.	R/W
b31 to b4	RSPN[27:0]	Region-Start Page Number	Page number where the region starts, for use in region determination	R/W

RSPN[27:0] Bits (Region-Start Page Number)

These bits specify the page number where the region starts.

13.2.2 Region-n End Page Number Register (REPAGEn) (n = 0 to 7)

Addresses: REPAGE0 0008 6404h, REPAGE1 0008 640Ch, REPAGE2 0008 6414h, REPAGE3 0008 641Ch
REPAGE4 0008 6424h, REPAGE5 0008 642Ch, REPAGE6 0008 6434h, REPAGE7 0008 643Ch

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
	REPN[27:0]															
Value after reset:	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	REPN[27:0]												UAC[2:0]			V
Value after reset:	x	x	x	x	x	x	x	x	x	x	x	x	0	0	0	0

x: Undefined

Bit	Symbol	Bit Name	Function	R/W
b0	V	Valid Bit	0: Region setting invalid 1: Region setting valid	R/W
b3 to b1	UAC[2:0]	Access Control Bits in User Mode	b3 0: Reading prohibited 1: Reading permitted b2 0: Writing prohibited 1: Writing permitted b1 0: Execution prohibited 1: Execution permitted	R/W
b31 to b4	REPN[27:0]	Region-End Page Number	Page number where the region ends, for use in region determination	R/W

V Bit (Valid Bit)

This bit enables or disables the settings for the corresponding region.
This bit is cleared to 0 when the region invalidation operation register (MPOPI) invalidates all access-controlled areas.

UAC[2:0] Bits (Access Control Bits in User Mode)

These bits specify the access control in user mode.

REPN[27:0] Bits (Region-End Page Number)

These bits specify the page number where the region ends.
Specify a value that is greater than or equal to the page number where the corresponding region starts. The page specified by the region-end page number is part of the target region for memory protection.

13.2.3 Memory-Protection Enable Register (MPEN)

Address: 0008 6500h

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	MPEN
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Function	R/W
b0	MPEN	Memory-Protection Enable	1: The memory protection is enabled. 0: The memory protection is disabled.	R/W
b31 to b1	—	Reserved	The read value is 0. The write value should always be 0	R/W

MPEN Bit (Memory-Protection Enable)

This bit enables or disables the memory protection.

After 1 has been written to this bit, address checking for memory protection by the CPU starts on the execution of a branch instruction (RTE and RTFI) that shifts operation to the user mode.

13.2.4 Background Access Control Register (MPBAC)

Address: 0008 6504h

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	—	—	—	—	UBAC[2:0]			—
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Function	R/W
b0	—	Reserved	The read value is 0. The write value should always be 0.	R/W
b3 to b1	UBAC[2:0]	Background Access Control Bits in User Mode	b3 0: Reading prohibited 1: Reading permitted b2 0: Writing prohibited 1: Writing permitted b1 0: Execution prohibited 1: Execution permitted	R/W
b31 to b4	—	Reserved	The read value is 0. The write value should always be 0.	R/W

UBAC[2:0] Bits (Background Access Control Bits in User Mode)

These bits specify the background access control in user mode.

13.2.5 Memory-Protection Error Status-Clearing Register (MPECLR)

Address: 0008 6508h

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	CLR
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Function	R/W
b0	CLR	Error Status-Clearing	[Reading] 0: Fixed value for reading [Writing] 0: Nothing is done. 1: The DRW, DA, and IA bits in the MPESTS are cleared to 0.	R/W
b31 to b1	—	Reserved	The read value is 0. The write value should always be 0.	R/W

CLR Bit (Error Status-Clearing)

This bit clears the data read/write bit (DRW), the data memory-protection error generated bit (DA), and the instruction memory-protection error generated bit (IA) in the memory-protection error status register (MPESTS) to 0.

13.2.6 Memory-Protection Error Status Register (MPESTS)

Address: 0008 650Ch

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	—	—	—	—	—	DRW	DA	IA
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Function	R/W
b0	IA	Instruction Memory-Protection Error Generated Bit	0: No instruction memory-protection error was generated. 1: Instruction memory-protection error was generated.	R
b1	DA	Data Memory-Protection Error Generated Bit	0: No data memory-protection error was generated. 1: Data memory-protection error was generated.	R
b2	DRW	Data Read/Write Bit	0: Data were read. 1: Data were written.	R
b31 to b3	—	Reserved	The read value is 0. The write value should always be 0.	R/W

IA Bit (Instruction Memory-Protection Error Generated Bit)

This bit indicates the state of memory-protection error generation by instruction execution.

Setting the error status-clearing bit (CLR) in the memory-protection error status-clearing register (MPECLR) to 1 clears this bit to 0.

DA Bit (Data Memory-Protection Error Generated Bit)

This bit indicates the state of memory-protection error generation by operand access.

Setting the error status-clearing bit (CLR) in the memory-protection error status-clearing register (MPECLR) to 1 clears this bit to 0.

DRW Bit (Data Read/Write Bit)

For a memory-protection error produced by operand access, this bit indicates the read/write attribute of the access operation. This bit is only valid when the data memory-protection error generated bit (DA) is 1.

Setting the error status-clearing bit (CLR) in the memory-protection error status-clearing register (MPECLR) to 1 clears this bit to 0.

13.2.7 Data Memory-Protection Error Address Register (MPDEA)

Address: 0008 6514h

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
	DEA[31:0]															
Value after reset:	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	DEA[31:0]															
Value after reset:	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

x: Undefined

Bit	Symbol	Bit Name	Function	R/W
b31 to b0	DEA[31:0]	Data Memory-Protection Error Address	Data memory-protection error address	R

DEA[31:0] Bits (Data Memory-Protection Error Address)

These bits retain the address for which operand access generated a memory-protection error.

13.2.8 Region Search Address Register (MPSA)

Address: 0008 6520h

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
	SA[31:0]															
Value after reset:	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	SA[31:0]															
Value after reset:	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

x: Undefined

Bit	Symbol	Bit Name	Function	R/W
b31 to b0	SA[31:0]	Region Search Address	Address for region searching	R/W

SA[31:0] Bits (Region Search Address)

These bits specify the address for use in comparison with region-start addresses in the region-n start page number registers (RSPAGEn) and region-end addresses in the region-n end page number registers (REPAGEn).

13.2.9 Region Search Operation Register (MPOPS)

Address: 0008 6524h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	S
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Function	R/W
b0	S	Region Search Operation	[Reading] 0: Fixed value for reading [Writing] 0: Nothing is done. 1: A region-search operation proceeds.	R/W
b15 to b1	—	Reserved	The read value is 0. The write value should always be 0.	R/W

S Bit (Region Search Operation)

Setting this bit to 1 makes the memory-protection unit perform a region-search operation. The address specified in the region search address register (MPSA) is compared with the address information for individual regions to search for a hitting region.

The result of searching is stored in the data-hit region bits (HITD[7:0]) of the data-hit region register (MHITD). Moreover, the logical OR of the respective access control bits for hitting regions is stored in the data-hit region access control bits (UHACD[2:0]) in user mode.

13.2.10 Region Invalidation Operation Register (MPOPI)

Address: 0008 6526h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	INV
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Function	R/W
b0	INV	Region Invalidate Start	[Reading] 0: Fixed value for reading [Writing] 0: Nothing is done. 1: All access-controlled areas are invalidated.	R/W
b15 to b1	—	Reserved	The read value is 0. The write value should always be 0.	R/W

INV Bit (Region Invalidate Start)

Setting this bit to 1 clears the valid (V) bits in all of the region-n end page number registers (REPAGEn) to 0. After a V bit is cleared to 0, all settings other than background access-control settings are invalid.

13.2.11 Instruction-Hit Region Register (MHITI)

Address: 0008 6528h

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
	—	—	—	—	—	—	—	—	HITI[7:0]							
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	—	—	—	—	UHACI[2:0]			—
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Function	R/W
b0	—	Reserved	The read value is 0. The write value should always be 0.	R/W
b3 to b1	UHACI[2:0]	Instruction-Hit Region Access Control Bits in User Mode	b3 0: Reading prohibited 1: Read permitted b2 0: Writing prohibited 1: Writing permitted b1 0: Execution prohibited 1: Execution is permitted.	R
b15 to b4	—	Reserved	The read value is 0. The write value should always be 0.	R/W
b23 to b16	HITI[7:0]	Instruction-Hit Region	When the instruction memory-protection error generated (IA) bit in the MPESTS = 1, [b23:b16] = 0000 0000b indicates that attempted access to the background region led to an instruction memory-protection error. Other than above b23 0: Instruction memory-protection error was not generated in region 7. 1: Instruction memory-protection error was generated in region 7. b22 0: Instruction memory-protection error was not generated in region 6. 1: Instruction memory-protection error was generated in region 6. b21 0: Instruction memory-protection error was not generated in region 5. 1: Instruction memory-protection error was generated in region 5. b20 0: Instruction memory-protection error was not generated in region 4. 1: Instruction memory-protection error was generated in region 4. b19 0: Instruction memory-protection error was not generated in region 3. 1: Instruction memory-protection error was generated in region 3. b18 0: Instruction memory-protection error was not generated in region 2. 1: Instruction memory-protection error was generated in region 2. b17 0: Instruction memory-protection error was not generated in region 1. 1: Instruction memory-protection error was generated in region 1. b16 0: Instruction memory-protection error was not generated in region 0. 1: Instruction memory-protection error was generated in region 0.	R
b31 to b24	—	Reserved	The read value is 0. The write value should always be 0.	R/W

UHACI[2:0] Bits (Instruction-Hit Region Access Control Bits in User Mode)

These bits hold the user-mode access control bits (REPAGEn.UAC[2:0]) for the region where the instruction memory-protection error was generated.

If the error was generated in an overlap between regions, the value stored here is the logical OR of the user-mode access control bits for the corresponding regions (including the background region).

HITI[7:0] Bits (Instruction-Hit Region)

These bits indicate the region where an instruction memory-protection error was generated. These bits are set to 0000 0000b in response to the generation of an instruction memory-protection error in the background region.

13.2.12 Data-Hit Region Register (MHITD)

Address: 0008 652Ch

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
	—	—	—	—	—	—	—	—	HITD[7:0]							
Value after reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	—	—	—	—	UHACD[2:0]			—
Value after reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Function	R/W
b0	—	Reserved	The read value is 0. The write value should always be 0.	R/W
b3 to b1	UHACD[2:0]	Data-Hit Region Access Control Bits in User Mode	b3 0: Reading prohibited 1: Reading permitted b2 0: Writing prohibited 1: Writing permitted b1 0: Execution prohibited 1: Execution permitted	R
b15 to b4	—	Reserved	The read value is 0. The write value should always be 0.	R/W
b23 to b16	HITD[7:0]	Data-Hit Region	When the data memory-protection error generated (DA) bit = 1, [b23:b16] = 0000 0000b indicates that attempted access to the background region led to a data memory-protection error. Other than above b23 0: Neither a data memory-protection error nor a search hit was generated in region 7. 1: A data memory-protection error or search hit was generated in region 7. b22 0: Neither a data memory-protection error nor a search hit was generated in region 6. 1: A data memory-protection error or search hit was generated in region 6. b21 0: Neither a data memory-protection error nor a search hit was generated in region 5. 1: A data memory-protection error or search hit was generated in region 5. b20 0: Neither a data memory-protection error nor a search hit was generated in region 4. 1: A data memory-protection error or search hit was generated in region 4. b19 0: Neither a data memory-protection error nor a search hit was generated in region 3. 1: A data memory-protection error or search hit was generated in region 3. b18 0: Neither a data memory-protection error nor a search hit was generated in region 2. 1: A data memory-protection error or search hit was generated in region 2. b17 0: Neither a data memory-protection error nor a search hit was generated in region 1. 1: A data memory-protection error or search hit was generated in region 1. b16 0: Neither a data memory-protection error nor a search hit was generated in region 0. 1: A data memory-protection error or search hit was generated in region 0.	R
b31 to b24	—	Reserved	The read value is 0. The write value should always be 0.	R/W

UHACD[2:0] Bits (Data-Hit Region Access Control Bits in User Mode)

These bits hold the user-mode access control bits (REPAGEn.UAC[2:0]) that have been set for the region where a data memory-protection error was generated or the region that produced a hit in region searching.
When an error is generated in an overlap between regions or a hit was generated in region searching, the value stored here is the logical OR of the user-mode access control bits for the corresponding regions (including the background region).

HITD[7:0] Bits (Data-Hit Region)

These bits indicate the region where a data memory-protection error was generated or the region that produced a hit in a region search. These bits are set to 0000 0000b for a data memory-protection error generated in the background region.

Note: When access to a register of memory protection unit in user mode generates a data memory-protection error, the value in this register is cleared to 0000 0000h.

13.3 Functions

13.3.1 Memory Protection

Memory protection means monitoring, in accord with the access-control information that has been set for the individual access-control regions and the background region, whether or not access by programs running in user mode violates the access-control settings. The memory-protection unit notifies the CPU of access-control violations (or memory-protection errors) when they are detected, causing the CPU to start access-exception processing.
Memory protection is enabled by setting the memory-protection enable (MPEN) bit in the memory-protection enable (MPEN) register to 1.
An instruction memory-protection error is generated on detection of an instruction-execution violation and a data memory-protection error is generated on detection of an operand-access reading or writing violation. Operand access that leads to a data memory-protection error is not actually executed.

13.3.2 Region Search

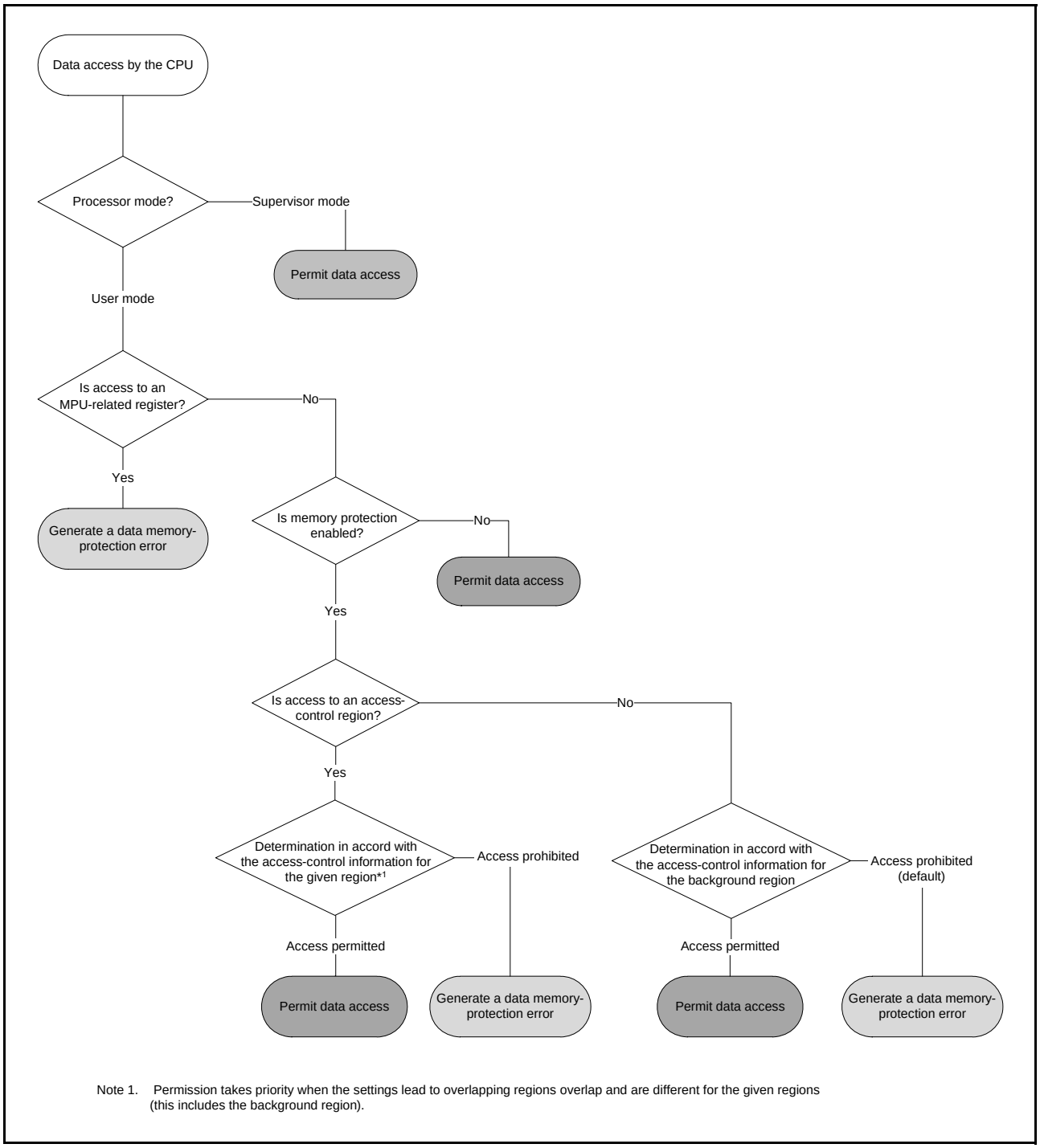
Region search means enquiry as to which of the eight specified access regions was “hit” and how the access-control information (permission to execute, to read, and to write) is set.
When the region search operation (S) bit in the region-search operation (MPOP) register is set to 1, the address specified in the region search address (MPSA) register is compared with the addresses for the individual regions. After a region search is executed, the data-hit region register (MHITD) indicates the logical OR of the access-control information for the region which was “hit” and for the other regions.

13.3.3 Protection of Registers Related to the Memory-Protection Unit

Registers related to the memory-protection unit are not accessible through means of access other than operand access by the CPU (i.e. by instruction fetching or DMA). Attempted access to registers related to the memory-protection unit in user mode through operand access by the CPU leads to a data memory-protection error regardless of whether or not memory protection is in effect at the given location.

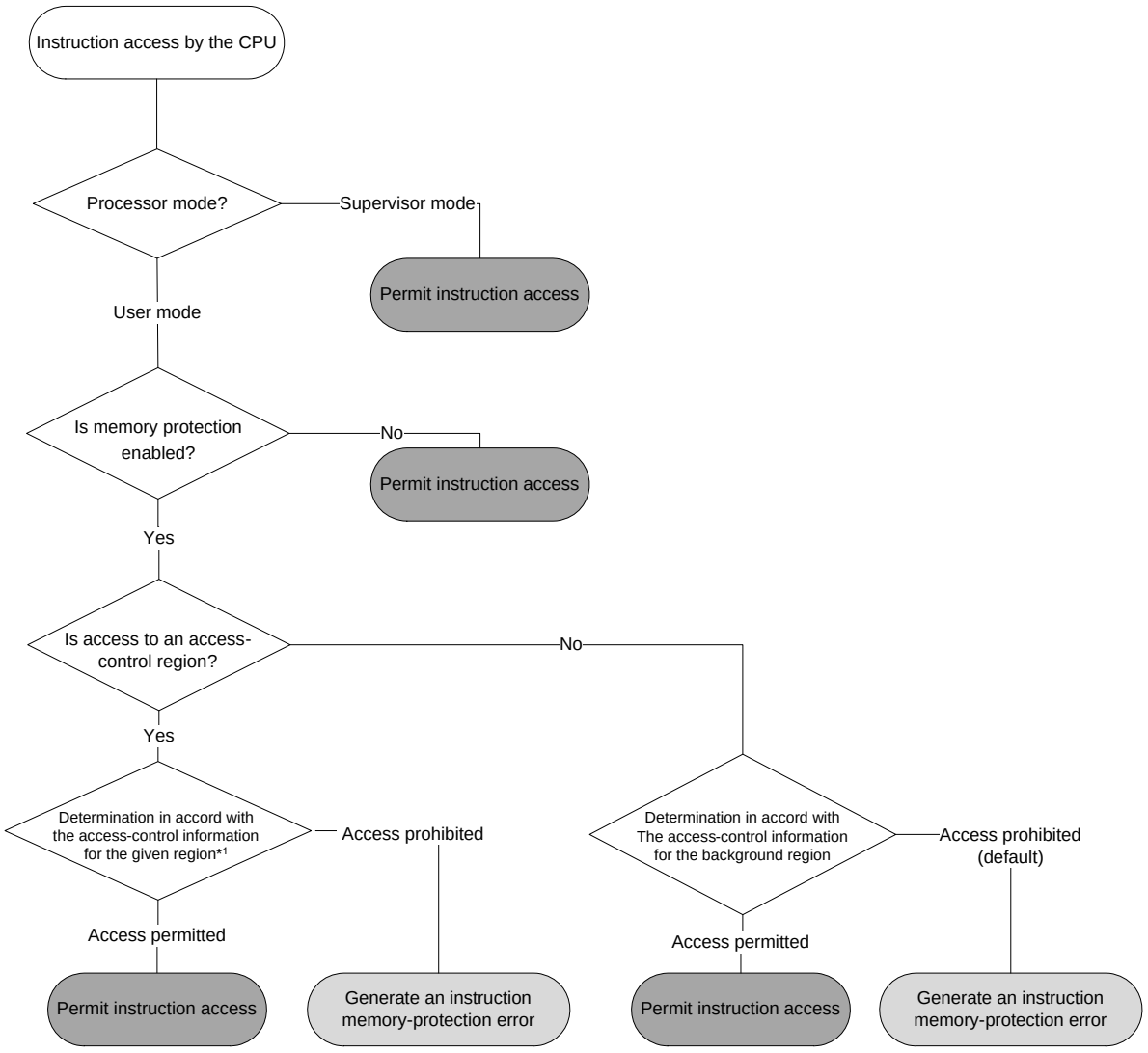
13.3.4 Flow for Determination of Access by the Memory-Protection Function

Figure 13.2 shows the flow of determination in the case of data access and Figure 13.3 shows the flow of determination in the case of instruction access.



Note 1. Permission takes priority when the settings lead to overlapping regions overlap and are different for the given regions (this includes the background region).

Figure 13.2 Flow of Determination for Data Access



Note 1. Permission takes priority when the settings lead to overlapping regions overlap and are not the same for the given regions (this includes the background region).

Figure 13.3 Flow of Determination for Instruction Access

13.4 Procedures for Using Memory Protection

13.4.1 Setting Access-Control Information

Access-control information for the various regions is set in supervisor mode.
Settings for up to eight access-control regions are made in the region-n start page number registers (RSPAGEn) and region-n end page number registers (REPAGEn), where n = 0 to 7.
Settings for the background access-control region are made in the background access-control register (MPBAC).

13.4.2 Enabling Memory Protection

Setting the memory-protection enable (MPEN) bit in the memory-protection enable (MPEN) register to 1 while operation is in supervisor mode enables memory protection.

13.4.3 Transition to User Mode

After updating the registers related to the memory-protection unit, be sure to read the registers for which writing was performed and check that the settings have been made as the final step before the transition to user mode.
Either of the methods below can be used for the transition from supervisor mode to user mode.

- Set the processor mode setting (PM) bit in the copy of the processor status word (PSW) saved in the stack area to 1 (the setting for user mode) and then execute an RTE instruction.
- Set the PM bit in the backup processor status word (BPSW) to 1 and then execute an RTFI instruction.

Note: Using an MVTC or POPC instruction to write to the PSW.PM bit is invalid. Use an RTE or RTFI instruction to update the value of the PSW.PM bit.

The memory-protection unit starts checking instruction-execution access and operand access by the CPU on the transition to user mode.

13.4.4 Processing in Response to Memory-Protection Errors

The CPU starts access-exception processing on detection of a violation of protection set up by the access-control information (i.e. a memory-protection error). For details on CPU operations in access-exception processing, refer to section 10., Exceptions.
To determine whether an instruction memory-protection error or data memory-protection error has been generated, check the values of the instruction memory-protection error generated (IA) and data memory-protection error generated (DA) bits in the memory-protection error status (MPESTS) register from within the exception-processing routine.
After confirming the type of error, clear the memory-protection error status (MPESTS) register by writing 1 to the status clearing (MPE) bit in the memory-protection error status clearing (MPECLR) register.

(1) When a data memory-protection error is generated

Access-exception processing by the CPU saves the address of the instruction that led to the memory-protection error on the stack. Furthermore, the address of the operand for which access led to a memory-protection error is stored in the data memory-protection error address register (MPDEA) and the region information for the region where the memory-protection error was generated is stored in the data-hit region register (MHITD).

- Violations of access control in access to valid regions 0 to 7

The data-hit region bits (MHITD.HITD[7:0]) with the same region number as the region where the error occurred is set to 1. In user mode, the logical “or” of the region access-control information for the location where the error occurred is set in the data-hit region access-control bits (MHITD.UHACD[2:0]).

- Violations of access control for the background region, besides access to valid regions 0 to 7

The data-hit region bits (MHITD.HITD[7:0]) are set to 0000 0000b. In user mode, the access-control information for the background region is set in the data-hit region access-control bits (MHITD.UHACD[2:0]).

Referring to this information can pinpoint the sources of errors.

(2) When an instruction memory-protection error is generated

Access-exception processing by the CPU saves the address of the instruction that led to the memory-protection error on the stack. Furthermore, the region information for the region where the memory-protection error was generated is stored in the instruction-hit region register (MHITI).

- Violations of access control in access to valid regions 0 to 7

The instruction-hit region bit (MHITD.HITI[7:0]) with the same region number as the region where the error occurred is set to 1. In user mode, the logical “or” of the region access-control information for the location where the error occurred is set in the instruction-hit region access-control bits (MHITI.UHACI[2:0]).

- Violations of access control for the background region, besides access to valid regions 0 to 7

The instruction-hit region bits (MHITI.HITI[7:0]) are set to 0000 0000b. In user mode, the access-control information for the background region is set in the instruction-hit region access-control bits (MHITI.UHACI[2:0]).

Referring to this information can pinpoint the sources of errors.

14. Data Transfer Controller (DTC)

The RX62T Group incorporates a data transfer controller (DTC).
The DTC is activated by an interrupt request to control data transfer.

14.1 Overview

Table 14.1 lists the specifications of the DTC, and Figure 14.1 shows a block diagram of the DTC.

Table 14.1 DTC Specifications

Item	Description
Transfer mode	• Normal transfer mode A single activation leads to a single data transfer. • Repeat transfer mode A single activation leads to a single data transfer. The transfer address is returned to the transfer start address after the number of data transfers corresponding to "repeat size". The maximum repeat size is 256. • Block transfer mode A single activation leads to the transfer of a single block. The maximum block size is 256.
Transfer channel	• Channel transfer corresponding to the interrupt source is possible (transferred by DTC activation request from the ICU). • Data of multiple channels can be transferred on a single activation source (chain transfer). • Either “executed when the counter is 0” or “always executed” can be selected for chain transfer.
Transfer space	• In short-address mode: 16 Mbytes (Areas from 0000 0000h to 007F FFFFh and FF80 0000h to FFFF FFFFh excepting reserved areas) • In full-address mode: 4 Gbytes (Area from 0000 0000h to FFFF FFFFh excepting reserved areas)
Data transfer units	• Length of a single data: 8, 16, or 32 bits • Number of data for a single block: 1 to 255 data
CPU interrupt source	• An interrupt request can be generated to the CPU on a DTC activation interrupt. • An interrupt request can be generated to the CPU after a single data transfer. • An interrupt request can be generated to the CPU after data transfer of specified volume.
Read skip	Transfer data read skip can be specified.
Write-back skip	When "fixed" is selected for transfer source address and/or transfer destination address, write-back skip execution is provided.

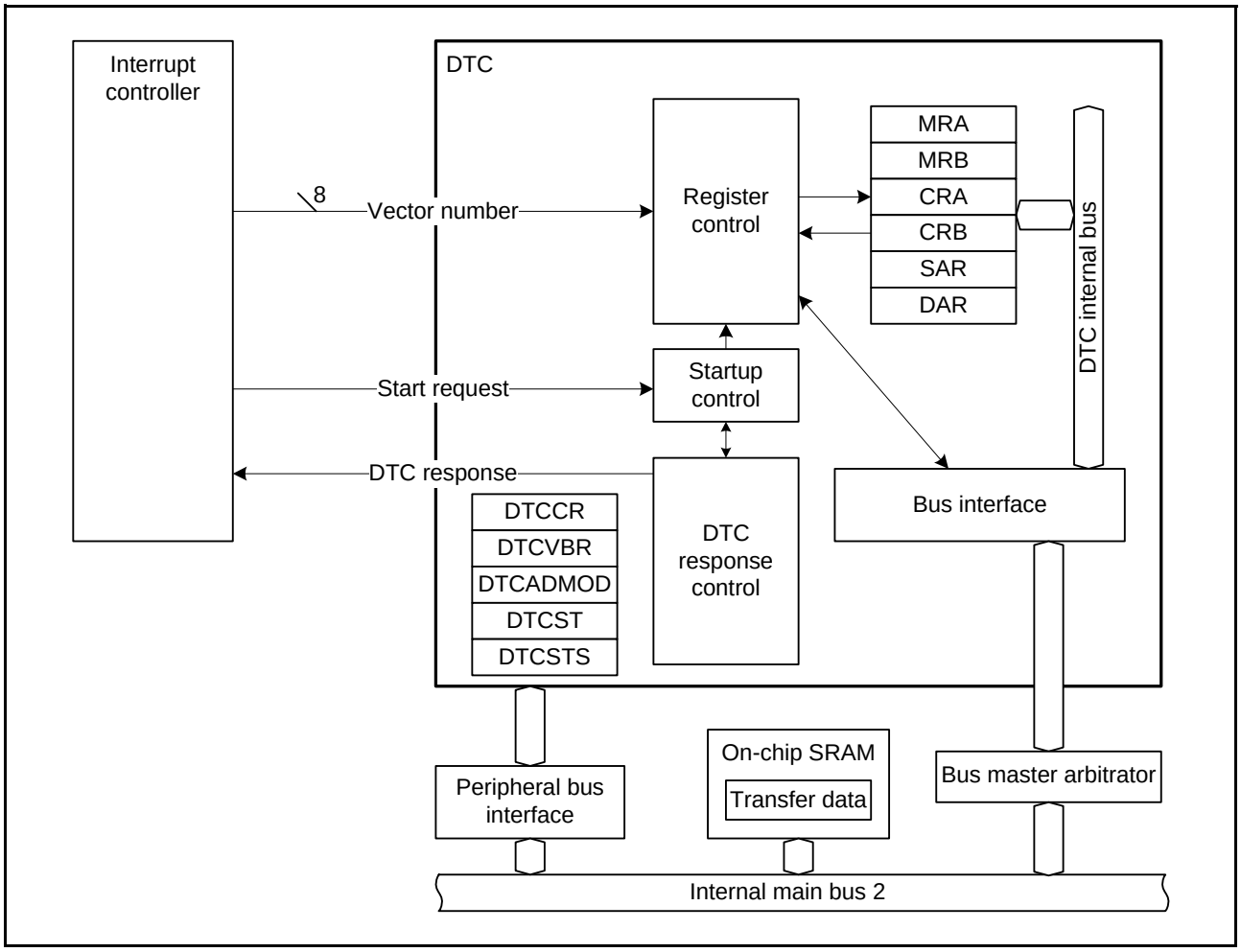


Figure 14.1 Block Diagram of the DTC

14.2 Register Descriptions

Table 14.2 lists the registers of the DTC.

Registers MRA, MRB, SAR, DAR, CRA, and CRB are DTC internal registers, which cannot be directly accessed from the CPU. Values to be set in the DTC internal registers are placed in the RAM area as transfer information data. When an activation request is generated, the DTC reads the transfer information data from the RAM area and set them in the internal registers. After the data transfer ends, the internal register contents are written back to the RAM area as transfer information data.

Table 14.2 Registers of the DTC

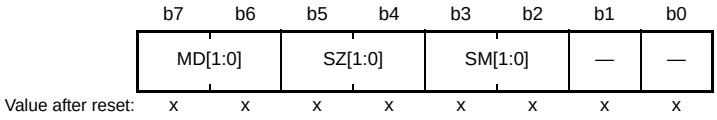
Register Name	Symbol	Value after Reset	Address	Access Size(Bits)
DTC mode register A	MRA	xxh	—	—
DTC mode register B	MRB	xxh	—	—
DTC transfer source address register	SAR	xxxxxxxxh	—	—
DTC transfer destination address register	DAR	xxxxxxxxh	—	—
DTC transfer count register A	CRA	xxxxh	—	—
DTC transfer count register B	CRB	xxxxh	—	—
DTC control register	DTCCR	08h	0008 2400h	8 bits
DTC vector base register	DTCVBR	00000000h	0008 2404h	32 bits
DTC address mode register	DTCADMOD	00h	0008 2408h	8 bits
DTC module start register	DTCST	00h	0008 240Ch	8 bits
DTC status register	DTCSTS	0000h	0008 240Eh	16 bits

x : Undefined value

Note: • To activate the DTC, a setting of the DTCERn.DTCE bit (n = interrupt vector number) and IERm.IENj (m = 02h to 1Fh, j = 7 to 0) bits in the interrupt controller (ICU) is required. For details, refer to section 11, Interrupt Controller (ICU).

14.2.1 DTC Mode Register A (MRA)

Address: (inaccessible directly from the CPU)



x: Undefined

Bit	Symbol	Bit Name	Description	R/W
b1, b0	—	Reserved	These bits are always read as undefined. The write value should be 0.	—
b3, b2	SM[1:0]	Transfer Source Address Addressing Mode	b3 b2 0 0: SAR value is fixed (Write-back to SAR is skipped) 0 1: SAR value is fixed (Write-back to SAR is skipped) 1 0: SAR value is incremented after data transfer (+1 when SZ[1:0] bits = 00b, +2 when SZ[1:0] bits = 01b, +4 when SZ[1:0] bits = 10b) 1 1: SAR value is decremented after data transfer (-1 when SZ[1:0] bits = 00b, -2 when SZ[1:0] bits = 01b, -4 when SZ[1:0] bits = 10b)	—
b5, b4	SZ[1:0]	DTC Data Transfer Size	b5 b4 0 0: Byte transfer 0 1: Word transfer 1 0: Longword transfer 1 1: Setting prohibited	—
b7, b6	MD[1:0]	DTC Transfer Mode Select	b7 b6 0 0: Normal transfer mode 0 1: Repeat transfer mode 1 0: Block transfer mode 1 1: Setting prohibited	—

MRA is used to select the operating mode of the DTC.
MRA cannot be accessed directly from the CPU.

SM[1:0] Bits (Transfer Source Address Addressing Mode)

These bits specify the SAR operation after data transfer.

SZ[1:0] Bits (DTC Data Transfer Size)

These bits specify the transfer data size.

MD[1:0] Bits (DTC Transfer Mode Select)

These bits specify the transfer mode of the DTC.

14.2.2 DTC Mode Register B (MRB)

Address: (inaccessible directly from the CPU)

	b7	b6	b5	b4	b3	b2	b1	b0
	CHNE	CHNS	DISEL	DTS	DM[1:0]		—	—
Value after reset:	x	x	x	x	x	x	x	x

x: Undefined

Bit	Symbol	Bit Name	Description	R/W
b1, b0	—	Reserved	These bits are always read as undefined. The write value should be 0.	—
b3, b2	DM[1:0]	Transfer Destination Address Addressing Mode	b3 b2 0 0: DAR value is address fixed (Write-back to DAR is skipped) 0 1: DAR value is address fixed (Write-back to DAR is skipped) 1 0: DAR value is incremented after data transfer (+1 when SZ[1:0] bits in MRA = 00b, +2 when SZ[1:0] bits = 01b, +4 when SZ[1:0] bits = 10b) 1 1: DAR value is decremented after data transfer (-1 when SZ[1:0] bits in MRA = 00b, -2 when SZ[1:0] bits = 01b, -4 when SZ[1:0] bits = 10b)	—
b4	DTS	DTC Transfer Mode Select	0: Destination side is repeat area or block area 1: Source side is repeat area or block area	—
b5	DISEL	DTC Interrupt Select	0: An interrupt request to the CPU is generated when specified data transfer is completed 1: An interrupt request to the CPU is generated each time DTC data transfer is performed	—
b6	CHNS	DTC Chain Transfer Select	0: Chain transfer is performed continuously 1: Chain transfer is performed only when the transfer counter is 0	—
b7	CHNE	DTC Chain Transfer Enable	0: Chain transfer is disabled 1: Chain transfer is enabled	—

MRB is used to select the operating mode of the DTC.
MRB cannot be accessed directly from the CPU.

DM[1:0] Bits (Transfer Destination Address Addressing Mode)

These bits specify the DAR operation after data transfer.

DTS Bit (DTC Transfer Mode Select)

The DTS bit specifies the side (transfer source or destination) to be a repeat area or block area in repeat transfer mode or block transfer mode.

DISEL Bit (DTC Interrupt Select)

The DISEL bit specifies whether to generate an interrupt request to the CPU each time DTC data transfer is performed or when specified data transfer is completed.

CHNS Bit (DTC Chain Transfer Select)

The CHNS bit selects the chain transfer condition.
When the next transfer is chain transfer, completion of specified transfer count is not checked and the interrupt status flag is not cleared. Moreover, an interrupt request to the CPU is not generated.

CHNE Bit (DTC Chain Transfer Enable)

The CHNE bit enables or disables chain transfer.
The chain transfer condition is selected by the CHNS bit.
For details of chain transfer, see section 14.4.6, Chain Transfer.

14.2.3 DTC Transfer Source Address register (SAR)

Address: (inaccessible directly from the CPU)

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
Value after reset:	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

x: Undefined

SAR is used to set the transfer source start address.
In full-address mode, 32 bits are valid.
In short-address mode, lower 24 bits are valid and upper 8 bits (b31 to b24) are ignored. The address of this register is extended by the value specified by b23.
SAR cannot be accessed directly from the CPU.

14.2.4 DTC Transfer Destination Address Register (DAR)

Address: (inaccessible directly from the CPU)

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
Value after reset:	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

x: Undefined

DAR is used to set the transfer destination start address.
In full-address mode, 32 bits are valid.

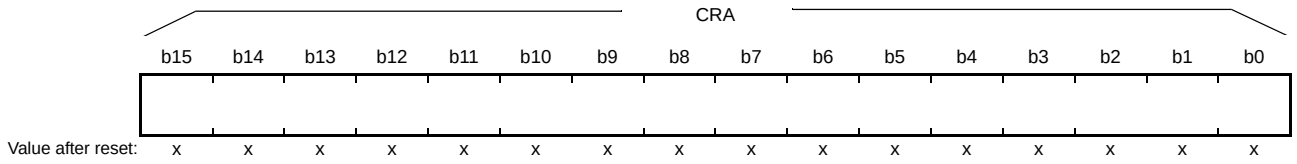
In short-address mode, lower 24 bits are valid and upper 8 bits (b31 to b24) are ignored. The address of this register is extended by the value specified by b23.

DAR cannot be accessed directly from the CPU.

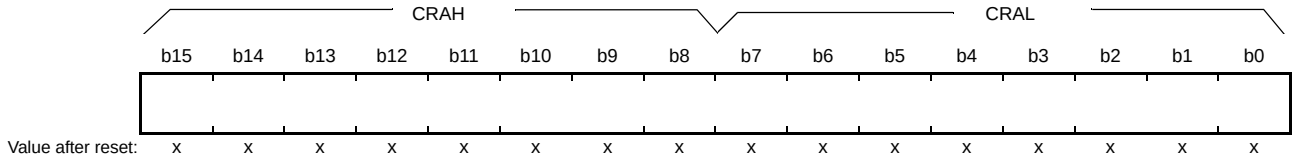
14.2.5 DTC Transfer Count Register A (CRA)

Address: (inaccessible directly from the CPU)

- Normal transfer mode



- Repeat transfer mode/block transfer mode



x: Undefined

Note 1. The function depends on transfer mode.

Symbol	Register Name	Description	R/W
CRAL	Transfer Counter A Lower Register	Set transfer count.	—
CRAH	Transfer Counter A Upper Register		—

Note: • Set CRAH and CRAL to the same value in repeat transfer mode and block transfer mode.

CRA is used to set the transfer count of the DTC.
The function of this register depends on transfer mode.
CRA cannot be accessed directly from the CPU.

(1) Normal transfer mode (MD[1:0] bits in MRA = 00b)

CRA functions as a 16-bit transfer counter in normal transfer mode.
The transfer count is 1, 65535, and 65536 when the set value is 0001h, FFFFh, and 0000h, respectively.
The CRA value is decremented (-1) at each data transfer.

(2) Repeat transfer mode (MD[1:0] bits in MRA = 01b)

The CRAH register retains transfer count and the CRAL register functions as an 8-bit transfer counter.
The transfer count is 1, 255, and 256 when the set value is 01h, FFh, and 00h, respectively.
The CRAL value is decremented (-1) at each data transfer. When it reaches 00h, the CRAH value is transferred to CRAL.

(3) Block transfer mode (MD[1:0] bits in MRA = 10b)

The CRAH register retains block size and the CRAL register functions as an 8-bit block size counter.
The transfer count is 1 and 255 when the set value is 01h and FFh, respectively. Setting a value of 00h is prohibited.
The CRAL value is decremented (-1) at each data transfer. When it reaches 00h, the CRAH value is transferred to CRAL.

14.2.6 DTC Transfer Count Register B (CRB)

Address: (inaccessible directly from the CPU)

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

x: Undefined

CRB is used to set the block transfer count for block transfer mode.
The block transfer count is 1, 65535, and 65536 when the set value is 0001h, FFFFh, and 0000h, respectively. The CRB value is decremented (-1) at each data transfer.
When normal transfer mode or repeat transfer mode is selected, set a value of FFFFh to the CRB.
CRB cannot be accessed directly from the CPU.

14.2.7 DTC Control Register (DTCCR)

Address: 0008 2400h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	RRS	—	—	—	—
Value after reset:	0	0	0	0	1	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b2 to b0	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W
b3	—	Reserved	This bit is always read as 1. The write value should be 1.	R/W
b4	RRS	DTC Transfer Data Read Skip Enable	0: Transfer data read is not skipped 1: Transfer data read is skipped when vector numbers match.	R/W
b7 to b5	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W

DTCCR is used to specify the control of the DTC.

RRS Bit (DTC Transfer Data Read Skip Enable)

The DTC vector number is always compared with the vector number in the previous startup process.
When these vector numbers match and the RRS bit is set to 1, DTC data transfer is performed without reading the transferred data. However, when the previous transfer was chain transfer, the transferred data is always read regardless of the value of RRS bit.
Furthermore, when the transfer counter (CRA register) became 0 during the previous normal transfer and when the transfer counter (CRB register) became 0 during the previous block transfer, the transferred data is always read regardless of the value of RRS bit.

14.2.8 DTC Vector Base Register (DTCVBR)

Address: 0008 2404h

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
					0	0	0	0	0	0	0	0	0	0	0	0
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

DTCVBR is used to set the base address for calculating the DTC vector table address.
The lower 12 bits (b11 to b0) are always 0 and cannot be modified.
The upper 4 bits (b31 to b28) are ignored, and the address of this register is extended by the value specified by b27.

14.2.9 DTC Address Mode Register (DTCADMOD)

Address: 0008 2408h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	SHORT
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	SHORT	Short-Address Mode	0: Full-address mode 1: Short-address mode	R/W
b7 to b1	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W

DTCADMOD is used to select an address mode that specifies DTC's accessible area.

SHORT Bit (Short-Address Mode)

Full-address mode allows the DTC to access to a 4GB space (00000000h to FFFFFFFFh).
Short-address mode allows the DTC to access to a 16MB space (00000000h to 007FFFFFh and FF800000h to FFFFFFFFh).

14.2.10 DTC Module Start Register (DTCST)

Address: 0008 240Ch

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	DTCST
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	DTCST	DTC Module Start	0: DTC module stop 1: DTC module start	R/W
b7 to b1	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W

DTCST is used to start or stop the DTC module.

DTCST Bit (DTC Module Start)

Set the DTCST bit to 1 to enable the DTC to accept start requests. When this bit is cleared to 0, start requests are no longer accepted.

If this bit is cleared to 0 during data transfer, the accepted start request is active until the processing is completed.

To enable transitions to the module-stop state, all-module clock stop mode, software-standby mode, or deep software-standby mode, the DTCST bit must be set to "0".

For details on the facilities for transitions to the module-stop state, all-module clock stop mode, software-standby mode, and deep software-standby mode, refer to section 14.8, Low-Power Consumption Function and section 9, Low Power Consumption.

14.2.11 DTC Status Register (DTCSTS)

Address: 0008 240Eh

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	ACT	—	—	—	—	—	—	—	VECN[7:0]							
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b7 to b0	VECN[7:0]	DTC-Activating Vector Number Monitoring	These bits indicate the vector number for the activating source when DTC transfer is in progress. The value is only valid if DTC transfer is in progress (the value of the ACT flag is 1).	R
b14 to b8	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W
b15	ACT	DTC Active Flag	0: DTC transfer operation is not in progress. 1: DTC transfer operation is in progress.	R

The DTCSTS is used to indicate the state of DTC transfer operation.

VECN[7:0] Bits (DTC-Activating Vector Number Monitoring)

While transfer by the DTC is in progress, these bits indicate the vector number corresponding to the activating source for the transfer.

When the DTCSTS register is read, the value read from the VECN[7:0] bits is valid if the value of the ACT flag was 1 (indicating DTC transfer in progress) and invalid if the value of the ACT flag was 0 (indicating no current DTC transfer).

See Table 14.3 for the correspondence between activating sources and vector numbers.

ACT Bit (DTC Active Flag)

This bit indicates the state of DTC transfer operation.

[Setting condition]

- When the DTC is activated by a start request

[Clearing condition]

- When transfer by the DTC is completed in response to a start request.

14.3 Sources of Activation

The DTC is activated by an interrupt request. Setting the DTCERn.DTCE bit (where n is the interrupt vector number of the given interrupt) of the ICU to 1 selects the corresponding interrupt as an activation source for the DTC.
For the software activation (SWINT), see section 11, Interrupt Controller (ICU).
On completion of a single round of data transfer (or the last of the consecutive transfers in the case of a chained transfer), follow the procedure below.

- On completion of a specified round of data transfer, the DTCERn.DTCE bit is cleared to 0 and an interrupt is requested to the CPU
- On completion of other transfers, if the MRB.DISEL bit is 1, an interrupt is requested to the CPU. If the MRB.DISEL bit is 0, the interrupt status flag (IRi.IR) of the activation source is cleared to 0.

14.3.1 Allocating Transfer Data and DTC Vector Table

The DTC reads the start address of transfer information data from the vector table for each activation source.
The vector table should be allocated so that the lower 12 bits of the base address (start address) are 0. The base address of the DTC vector table should be set in the DTC vector base register (DTCVBR).
Transfer information data is allocated in the RAM area. The start address of transfer information data (n) of vector No. n should be “vector table base address plus 4n”.
Transfer information data can be allocated with 3 longwords (short-address mode) or 4 longwords (full-address mode). Use the SHORT bit in DTCADMOD to select short-address mode (SHORT bit = 1) or full-address mode (SHORT bit = 0).
Figure 14.2 shows the correspondence between the DTC vector table and transfer information data. Figure 14.3 shows allocation of transfer information data in the RAM area. The lower address differs according to the endian mode of the allocation area. For details, see Figure 14.16.

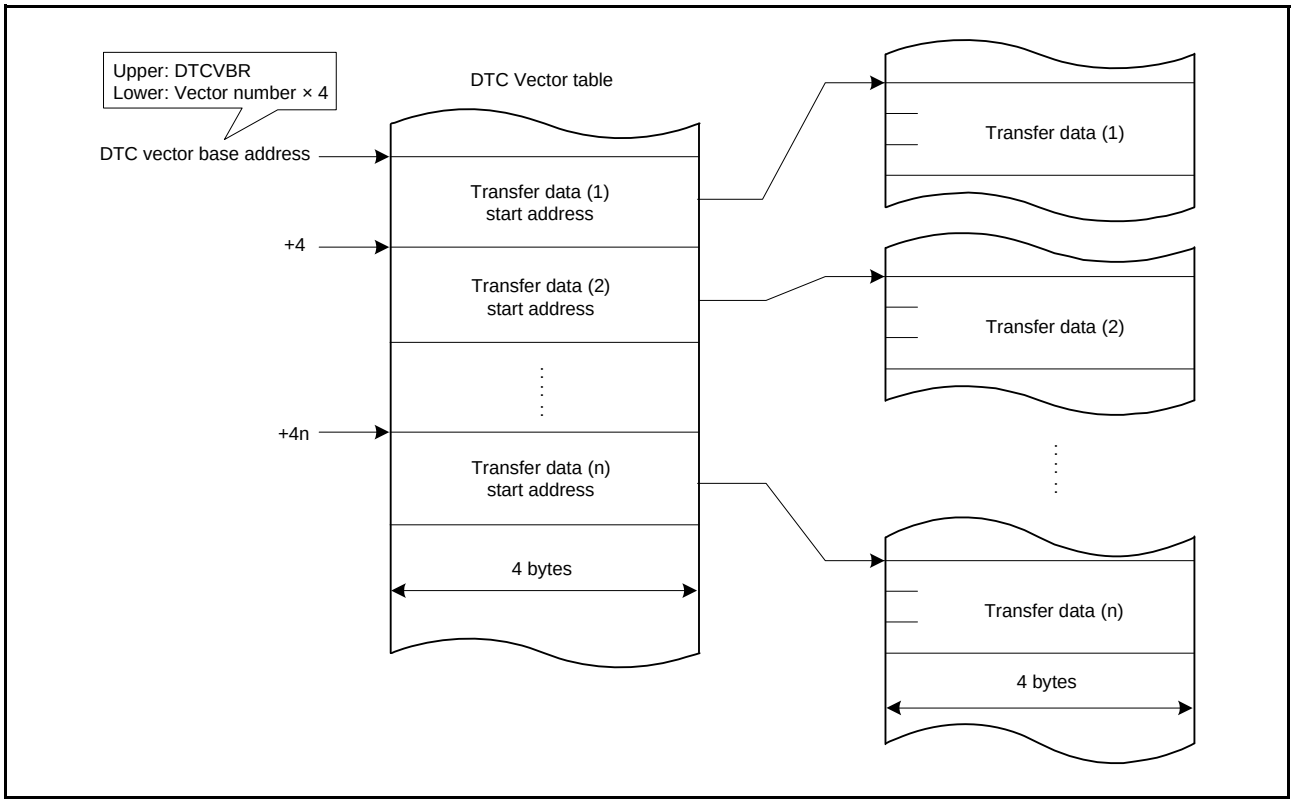


Figure 14.2 Correspondence between DTC Vector Table and Transfer Data

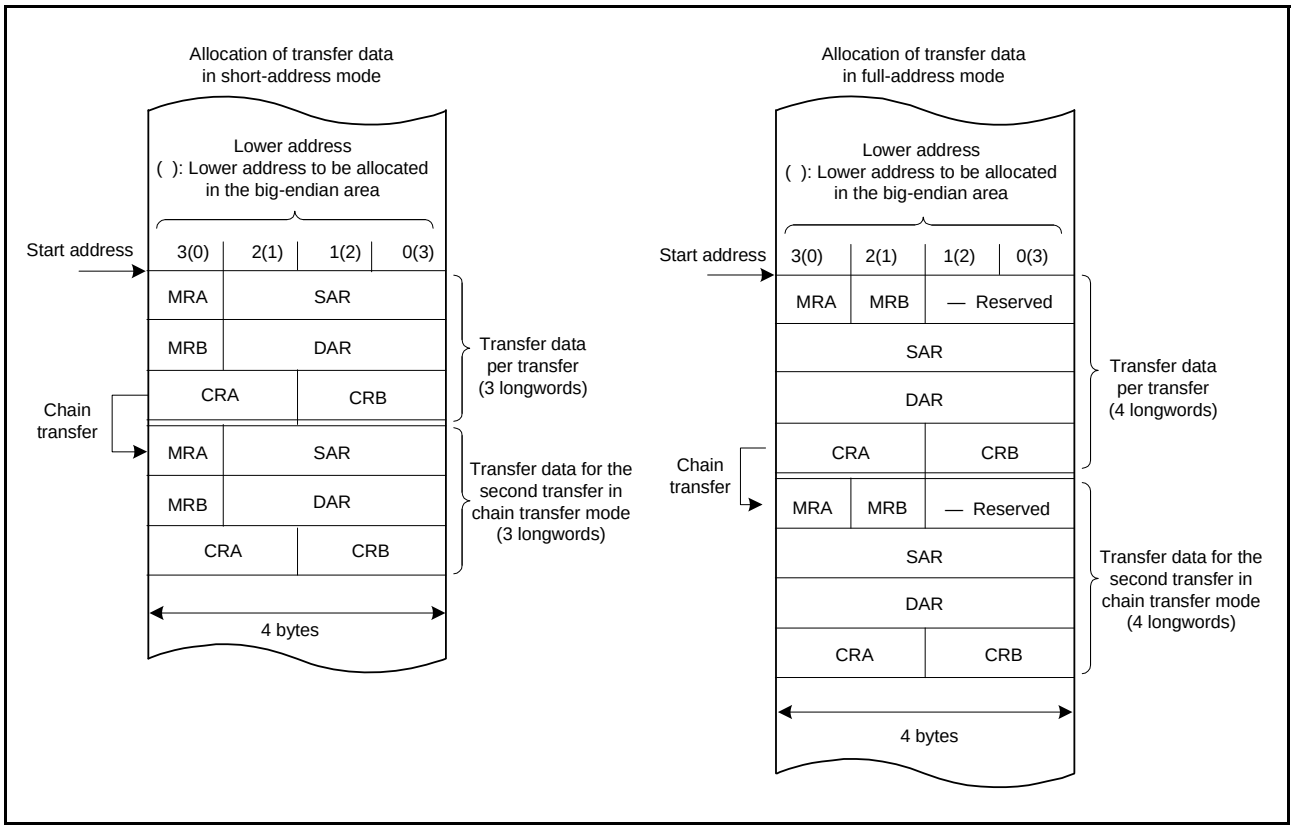


Figure 14.3 Allocation of Transfer Data in the RAM Area

14.3.2 Activation Sources and Vector Address

Table 14.3shows the correspondence between DTC activation sources and vector addresses.

Table 14.3 Correspondence between Interrupt Sources, DTC Vector Addresses, and the ICU.DTCERn Register (1 / 2)

Actication Request Generation Source	Actication Source	Vector Number	DTC Vector Address Offset	ICU.DTCERn	Priority *
ICU	SWINT	27	006Ch	ICU.DTCER027	High
CMT0	CMI0	28	0070h	ICU.DTCER028	
CMT1	CMI1	29	0074h	ICU.DTCER029	
CMT2	CMI2	30	0078h	ICU.DTCER030	
CMT3	CMI3	31	007Ch	ICU.DTCER031	
RSPI0	SPRI0	45	00B4h	ICU.DTCER045	
	SPTI0	46	00B8h	ICU.DTCER046	
External pin	IRQ0	64	0100h	ICU.DTCER064	
	IRQ1	65	0104h	ICU.DTCER065	
	IRQ2	66	0108h	ICU.DTCER066	
	IRQ3	67	010Ch	ICU.DTCER067	
	IRQ4	68	0110h	ICU.DTCER068	
	IRQ5	69	0114h	ICU.DTCER069	
	IRQ6	70	0118h	ICU.DTCER070	
	IRQ7	71	011Ch	ICU.DTCER071	
AD0	ADI0	98	0188h	ICU.DTCER098	
S12AD0	S12ADI0	102	0198h	ICU.DTCER102	
S12AD1	S12ADI1	103	019Ch	ICU.DTCER103	
Comparator	CMPI	106	01A8h	ICU.DTCER106	
MTU0	TGIA0	114	01C8h	ICU.DTCER114	
	TGIB0	115	01CCh	ICU.DTCER115	
	TGIC0	116	01D0h	ICU.DTCER116	
	TGID0	117	01D4h	ICU.DTCER117	
MTU1	TGIA1	121	01E4h	ICU.DTCER121	
	TGIB1	122	01E8h	ICU.DTCER122	
MTU2	TGIA2	125	01F4h	ICU.DTCER125	
	TGIB2	126	01F8h	ICU.DTCER126	
MTU3	TGIA3	129	0204h	ICU.DTCER129	
	TGIB3	130	0208h	ICU.DTCER130	
	TGIC3	131	020Ch	ICU.DTCER131	
	TGID3	132	0210h	ICU.DTCER132	
MTU4	TGIA4	134	0218h	ICU.DTCER134	
	TGIB4	135	021Ch	ICU.DTCER135	
	TGIC4	136	0220h	ICU.DTCER136	
	TGID4	137	0224h	ICU.DTCER137	
	TCIV4	138	0228h	ICU.DTCER138	
MTU5	TGIU5	139	022Ch	ICU.DTCER139	
	TGIV5	140	0230h	ICU.DTCER140	
	TGIW5	141	0234h	ICU.DTCER141	Low

Table 14.3 Correspondence between Interrupt Sources, DTC Vector Addresses, and the ICU.DTCERn Register (2 / 2)

Actication Request Generation Source	Actication Source	Vector Number	DTC Vector Address Offset	ICU.DTCERn	Priority *
MTU6	TGIA6	142	0238h	ICU.DTCER142	High
	TGIB6	143	023Ch	ICU.DTCER143	
	TGIC6	144	0240h	ICU.DTCER144	
	TGID6	145	0244h	ICU.DTCER145	
MTU7	TGIA7	149	0254h	ICU.DTCER149	
	TGIB7	150	0258h	ICU.DTCER150	
	TGIC7	151	025Ch	ICU.DTCER151	
	TGID7	152	0260h	ICU.DTCER152	
	TCIV7	153	0264h	ICU.DTCER153	
GPT0	GTCIA0	174	02B8h	ICU.DTCER174	
	GTCIB0	175	02BCh	ICU.DTCER175	
	GTCIC0	176	02C0h	ICU.DTCER176	
	GTCIE0	177	02C4h	ICU.DTCER177	
	GTCIV0	178	02C8h	ICU.DTCER178	
	LOCO1	179	02CCh	ICU.DTCER179	
GPT1	GTCIA1	180	02D0h	ICU.DTCER180	
	GTCIB1	181	02D4h	ICU.DTCER181	
	GTCIC1	182	02D8h	ICU.DTCER182	
	GTCIE1	183	02DCh	ICU.DTCER183	
	GTCIV1	184	02E0h	ICU.DTCER184	
GPT2	GTCIA2	186	02E8h	ICU.DTCER186	
	GTCIB2	187	02ECh	ICU.DTCER187	
	GTCIC2	188	02F0h	ICU.DTCER188	
	GTCIE2	189	02F4h	ICU.DTCER189	
	GTCIV2	190	02F8h	ICU.DTCER190	
GPT3	GTCIA3	192	0300h	ICU.DTCER192	
	GTCIB3	193	0304h	ICU.DTCER193	
	GTCIC3	194	0308h	ICU.DTCER194	
	GTCIE3	195	030Ch	ICU.DTCER195	
	GTCIV3	196	0310h	ICU.DTCER196	
SCI0	RXI0	215	035Ch	ICU.DTCER215	
	TXI0	216	0360h	ICU.DTCER216	
SCI1	RXI1	219	036Ch	ICU.DTCER219	
	TXI1	220	0370h	ICU.DTCER220	
SCI2	RXI2	223	037Ch	ICU.DTCER223	
	TXI2	224	0380h	ICU.DTCER224	
RIIC0	ICRXI0	247	03DCh	ICU.DTCER247	
	ICTXI0	248	03E0h	ICU.DTCER248	Low

Note: • Once the DTC has accepted an activation request, it does not accept further activation requests until transfer for that single request is completed, regardless of the priority order of the requests. However, if multiple activation requests are generated while DTC transfer is in progress, the DTC accepts the request with the highest priority when the transfer ends. If multiple activation requests are generated when the DTC module start register (DTCST) value is 0, the DTC accepts the request with the highest priority when the DTC enters the activation-enabled state (by setting DTCST to 1).

14.4 Operation

The DTC transfers data in accordance with the transfer data. Storage of the transfer data in the RAM area is required before DTC operation.

When the DTC is activated, it reads the DTC vector corresponding to the vector number. Then the DTC reads transfer data from the transfer data store address pointed by the DTC vector, transfers data, and then writes back the transfer data after the data transfer. Storing transfer data in the RAM area allows data transfer of arbitrary number of channels.

There are three transfer modes: normal transfer mode, repeat transfer mode, and block transfer mode.

The DTC specifies a transfer source address in SAR and a transfer destination address in DAR. The values of these registers are incremented, decremented, or remain unchanged independently after data transfer.

Table 14.4 lists transfer modes of the DTC.

Table 14.4 Transfer Modes of the DTC

Transfer Mode	Data Size Transferred on a Single Activation Request	Increment/Decrement of Memory Address	Settable Transfer Count
Normal transfer mode	One byte/word/longword	Incremented/decremented by 1, 2, or 4 or address fixed	1 to 65536
Repeat transfer mode*1	One byte/word/longword	Incremented/decremented by 1, 2 or, 4 or address fixed	1 to 256*3
Block transfer mode*2	Block size specified in CRAH (1 to 255 bytes/words/longwords)	Incremented/decremented by 1, 2 or, 4 or address fixed	1 to 65536

Note 1. Set transfer source or transfer destination in the repeat area.
Note 2. Set transfer source or transfer destination in the block area.
Note 3. After data transfer of the specified count, the initial state is restored and the operation is continued (repeated).

Setting the CHNE bit in MRB to 1 allows multiple transfers (chain transfer) on a single startup source. Chain transfer is enabled when transfer counter = 0 by setting the CHNS bit in MRB to 1.

Figure 14.4 shows the operation flowchart of the DTC.Table 14.5 shows chain transfer conditions (excluding combinations of the second transfer and the third transfer, and combinations of subsequent transfers).

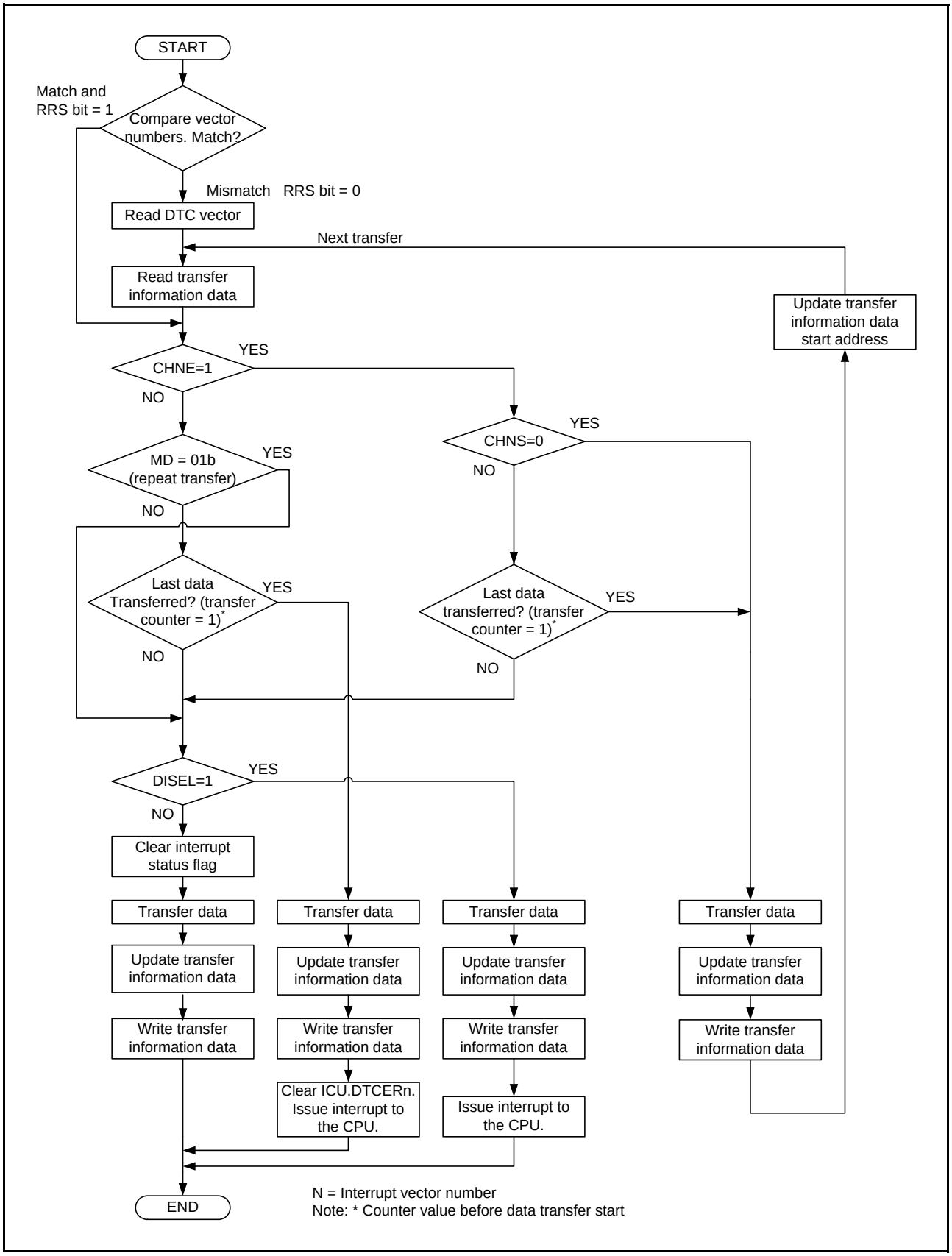


Figure 14.4 Operation Flowchart of the DTC

Table 14.5 Chain Transfer Conditions

First Transfer				Second Transfer*3				
CHNE Bit	CHNS Bit	DISEL Bit	Transfer Counter*1*2	CHNE Bit	CHNS Bit	DISEL Bit	Transfer Counter*1*2	DTC Transfer
0	—	0	Other than (1→0)	—	——	—	—	Ends after the first transfer
0	—	0	(1→0)	—	—	—	—	Ends after the first transfer with an interrupt request to the CPU
0	—	1	—	—	—	—	—	
1	0	—	—	0	—	0	Other than (1→0)	Ends after the second transfer
				0	—	0	(1→0)	Ends after the second transfer with an interrupt request to the CPU
				0	—	1	—	
1	1	0	Other than (1→*)	—	—	—	—	Ends after the first transfer
1	1	—	(1→*)	0	—	0	Other than (1→0)	Ends after the second transfer
				0	—	0	(1→0)	Ends after the second transfer with an interrupt request to the CPU
				0	—	1	—	
1	1	1	Other than (1→*)	—	—	—	—	Ends after the first transfer with an interrupt request to the CPU

Note 1. The registers to be used as transfer counters differ according to the transfer modes. Normal transfer mode: CRA, Repeat transfer mode: CRAL, Block transfer mode: CRB

Note 2. On the last data transfer, the counter value changes from 1 to 0 in normal or block transfer mode and changes from 1 to CRAH in repeat transfer mode. “1 → *” indicates both of these operations.

Note 3. Chain transfer can be selected for the second or subsequent transfers. The condition combination of “second transfer and CHNE bit = 1” is omitted.

14.4.1 Transfer Data Read Skip Function

Vector address read and transfer data read can be skipped by the setting of the RRS bit in DTCCR.
When a DTC activation request is generated, the current DTC vector number is always compared with the DTC vector number in the previous startup process. When these vector numbers match and the RRS bit is set to 1, DTC data transfer is performed without reading the vector address and transfer data. However, when the previous transfer was chain transfer, the vector address and transfer data are always read. Furthermore, when the transfer counter (CRA register) became 0 during the previous normal transfer and when the transfer counter (CRB register) became 0 during the previous block transfer, transfer data is always read regardless of the value of RRS bit. Figure 14.13 shows an example of transfer data read skip.
To update the DTC vector table and transfer data, set the RRS bit to 0, update the DTC vector table and transfer data, and then set the RRS bit to 1. When the RRS bit is set to 0, the retained vector number is discarded and the DTC vector table and transfer data that are updated in the following startup process are read.

14.4.2 Transfer Data Write-Back Skip Function

When the SM[1:0] bits in MRA or the DM[1:0] bits in MRB are set to "address fixed", a part of transfer data is not written back. This function is performed independently of the setting of short-address mode or full-address mode. Table 14.6 lists transfer data write-back skip conditions and applicable registers.
The CRA and CRB registers are always written back independently of the setting of short-address mode or full-address mode. Furthermore, in full-address mode, write-back of the MRA and MRB registers are always skipped.

Table 14.6 Transfer Data Write-Back Skip Conditions and Applicable Registers

SM[1:0] Bits in MRA		DM[1:0] Bits in MRB		SAR Register	DAR Register
b3	b2	b3	b2		
0	0	0	0	Skip	Skip
0	0	0	1		
0	1	0	0		
0	1	0	1		
0	0	1	0	Skip	Write-back
0	0	1	1		
0	1	1	0		
0	1	1	1		
1	0	0	0	Write-back	Skip
1	0	0	1		
1	1	0	0		
1	1	0	1		
1	0	1	0	Write-back	Write-back
1	0	1	1		
1	1	1	0		
1	1	1	1		

14.4.3 Normal Transfer Mode

This mode allows 1-byte, 1-word, or 1-longword data transfer on a single startup source. The transfer count can be set to 1 to 65536.

Transfer source addresses and transfer destination addresses can be set to increment, decrement, or fixed independently.

This mode enables an interrupt request to the CPU to be generated at the end of specified-count transfer.

Table 14.7 lists register functions in normal transfer mode, and Figure 14.5 shows the memory map of normal transfer mode.

Table 14.7 Register Functions in Normal Transfer Mode

Register	Description	Value Written Back by Writing Transfer Data
SAR	Transfer source address	Increment/decrement/fixed*1
DAR	Transfer destination address	Increment/decrement/fixed*1
CRA	Transfer counter A	CRA - 1
CRB	Transfer counter B	Not updated

Note 1. Write-back operation is skipped in address-fixed mode.

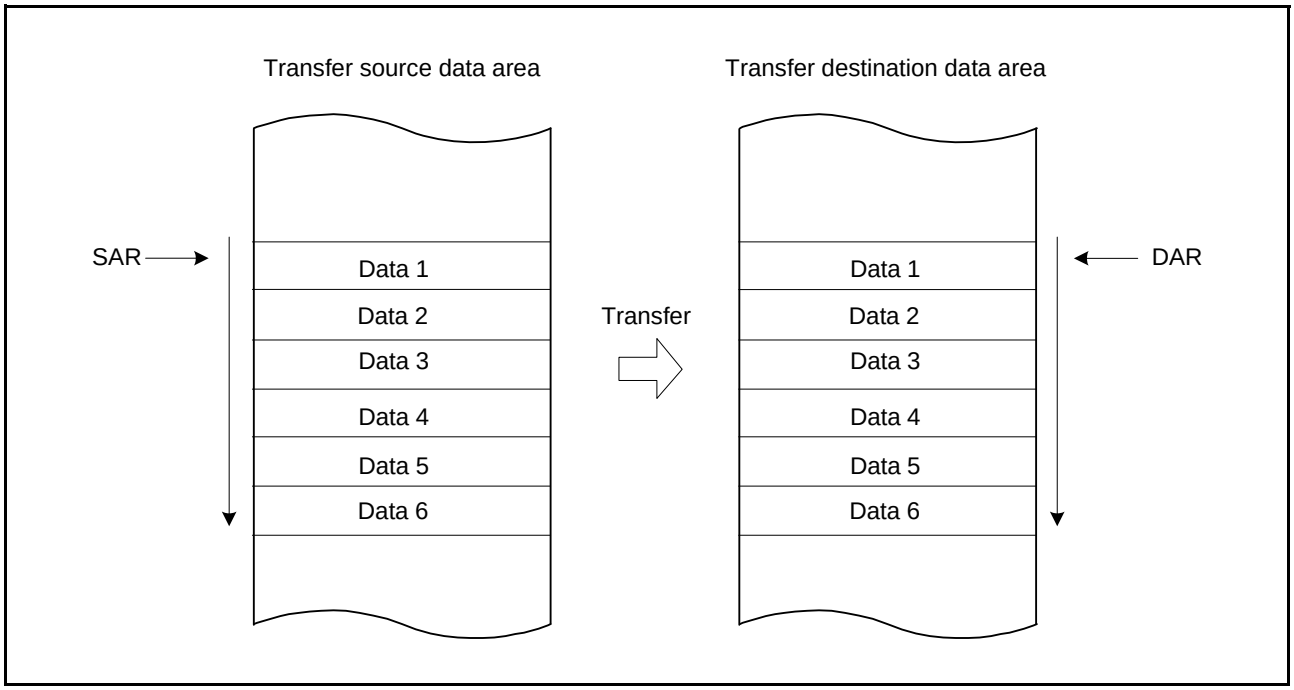


Figure 14.5 Memory Map of Normal Transfer Mode

14.4.4 Repeat Transfer Mode

This mode allows 1-byte, 1-word, or 1-longword data transfer on a single startup source.
Specify either transfer source or transfer destination for the repeat area by the DTS bit in MRB. The transfer count can be set to 1 to 256. When the specified-count transfer is completed, the initial value of the address register specified in the transfer counter and the repeat area is restored and transfer is repeated. The other address register is incremented or decremented continuously or remains unchanged.
When the transfer counter CRAL is decreased to 00h in repeat transfer mode, the CRAL value is updated to the value set in CRAH. Thus the transfer counter does not become 00h, which inhibits generation of interrupt request to the CPU when the DISEL bit in MRB is set to 0 (an interrupt request to the CPU is generated when specified data transfer is completed).
Table 14.8 lists the register functions in repeat transfer mode, and Figure 14.6 shows the memory map of repeat transfer mode.

Table 14.8 Register Functions in Repeat Transfer Mode

		Value Written Back by Writing Transfer Data	
Register	**Description**	**When CRAL is not 1**	**When CRAL is 1**
SAR	Transfer source address	Increment/decrement/fixed*1	(When the DTS bit in MRB is 0) Increment/decrement/fixed*1 (When the DTS bit in MRB is 1) SAR register initial value
DAR	Transfer destination address	Increment/decrement/fixed*1	(When the DTS bit in MRB is 0) DAR register initial value (When the DTS bit in MRB is 1) Increment/decrement/fixed*1
CRAH	Retains transfer counter	CRAH	CRAH
CRAL	Transfer counter A	CRAL - 1	CRAH
CRB	Transfer counter B	Not updated	Not updated

Note 1. Write-back is skipped in address-fixed mode.

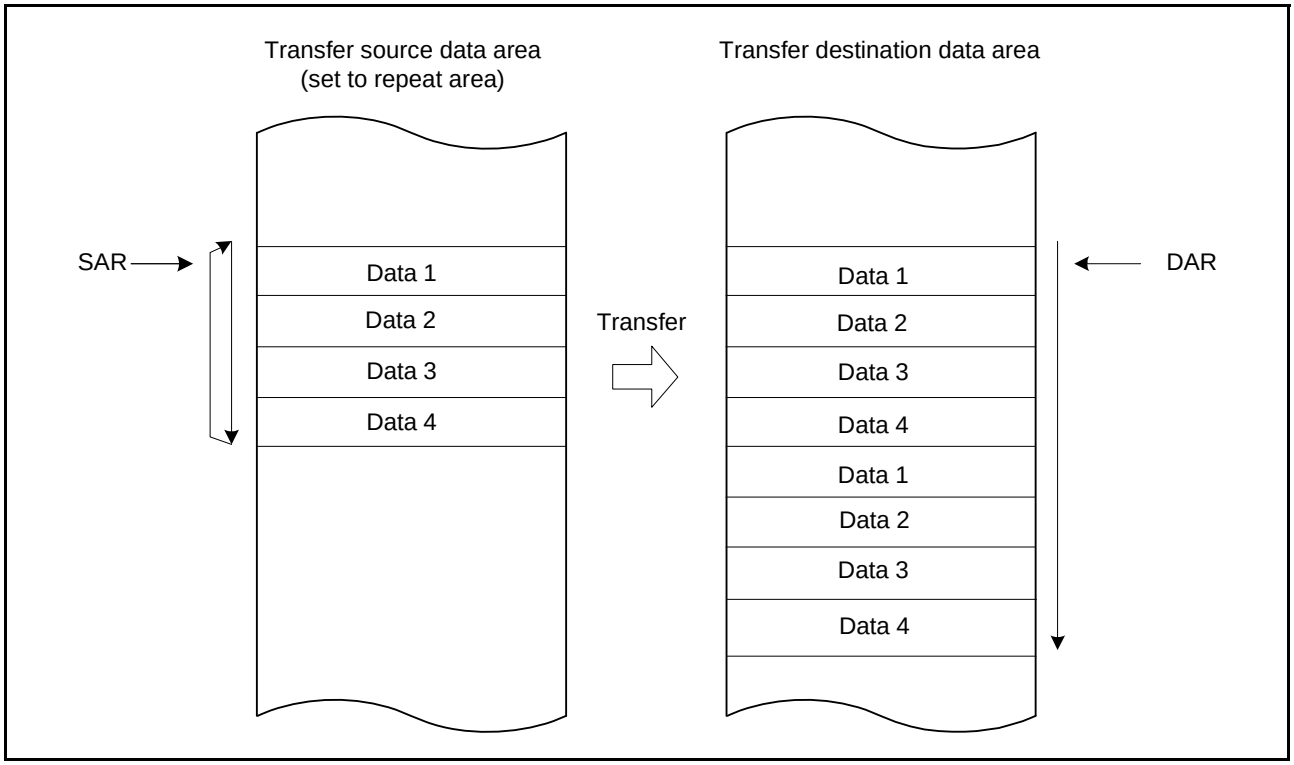


Figure 14.6 Memory Map of Repeat Transfer Mode (Transfer Source: Repeat Area)

14.4.5 Block Transfer Mode

This mode allows single-block data transfer on a single startup source.
Specify either transfer source or transfer destination for the block area by the DTS bit in MRB. The block size can be set to 1 to 255 bytes (or 1 to 255 words or 1 to 255 longwords).
When transfer of the specified one block is completed, the initial values of the block size counter CRAL and the address register (SAR when the DTS bit = 1 or DAR when the DTS bit = 0) specified in the block area are restored. The other address register is incremented or decremented continuously or remains unchanged.
The block transfer count can be set to 1 to 65536. This mode enables an interrupt request to the CPU to be generated at the end of specified-count block transfer.
Table 14.9 lists register functions in block transfer mode, and Figure 14.7 shows the memory map of block transfer mode.

Table 14.9 Register Functions in Block Transfer Mode

Register	Description	Value Written Back by Writing Transfer Data
SAR	Transfer source address	(When DTS bit in MRB is 0) Increment/decrement/fixed*1 (When DTS bit in MRB is 1) SAR register initial value
DAR	Transfer destination address	(When DTS bit in MRB is 0) DAR register initial value (When DTS bit in MRB is 1) Increment/decrement/fixed*1
CRAH	Retains block size	CRAH
CRAL	Block size counter	CRAH
CRB	Block transfer counter	CRB - 1

Note 1. Write-back is skipped in address-fixed mode.

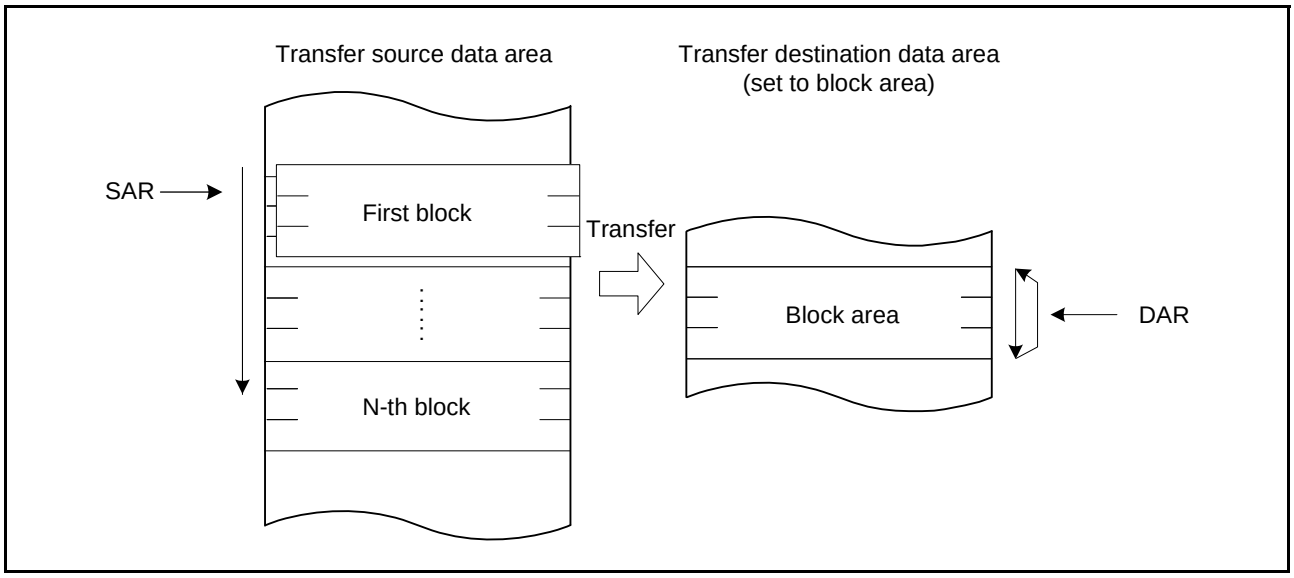


Figure 14.7 Memory Map of Block Transfer Mode (Transfer Destination: Block Area)

14.4.6 Chain Transfer

Setting the MRB.CHNE bit to "1" enables chained transfer. In chained transfer, multiple unit transfer operations are performed in response to a single request from an activation source.
When the MRB.CHNE bit is "1" and the MRB.CHNS bit is "0", an interrupt request is sent to the CPU on completion of the specified number of unit transfer operations unless the MRB.DISEL bit is "1" (selecting generation of an interrupt for the CPU after every round of data transfer), in which case an interrupt request for the CPU is not generated. Furthermore, the interrupt status flag is not affected when an interrupt signal is being used as an activation source.
Settings for the SAR, DAR, CRA, CRB, MRA, and MRB registers can be individually made.
Figure 14.8 shows operations in chained transfer.

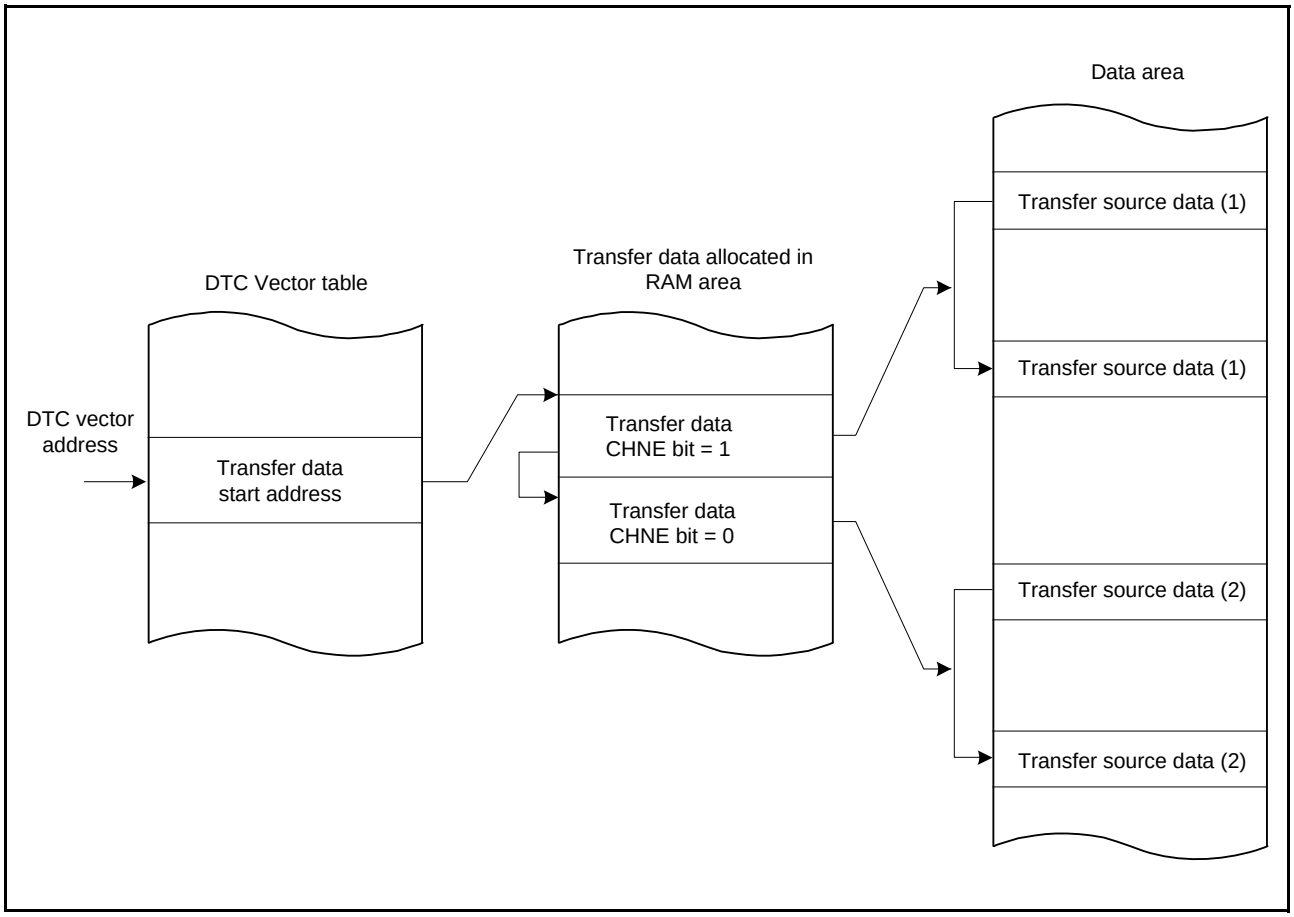


Figure 14.8 Chain Transfer Operation

When both the MRB.CHNE and MRB.CHNS bits are "1", chained transfer only proceeds on completion of the specified number of rounds of data transfer (that is, when the transfer counter becomes "0"). Even if the transfer mode is repeat transfer mode, chained transfer only proceeds on completion of the specified number of rounds of data transfer.
See Figure 14.5 for details of the conditions for chained transfer.

14.4.7 Operation Timing

Figure 14.9 to Figure 14.12 show examples of DTC operation timing.

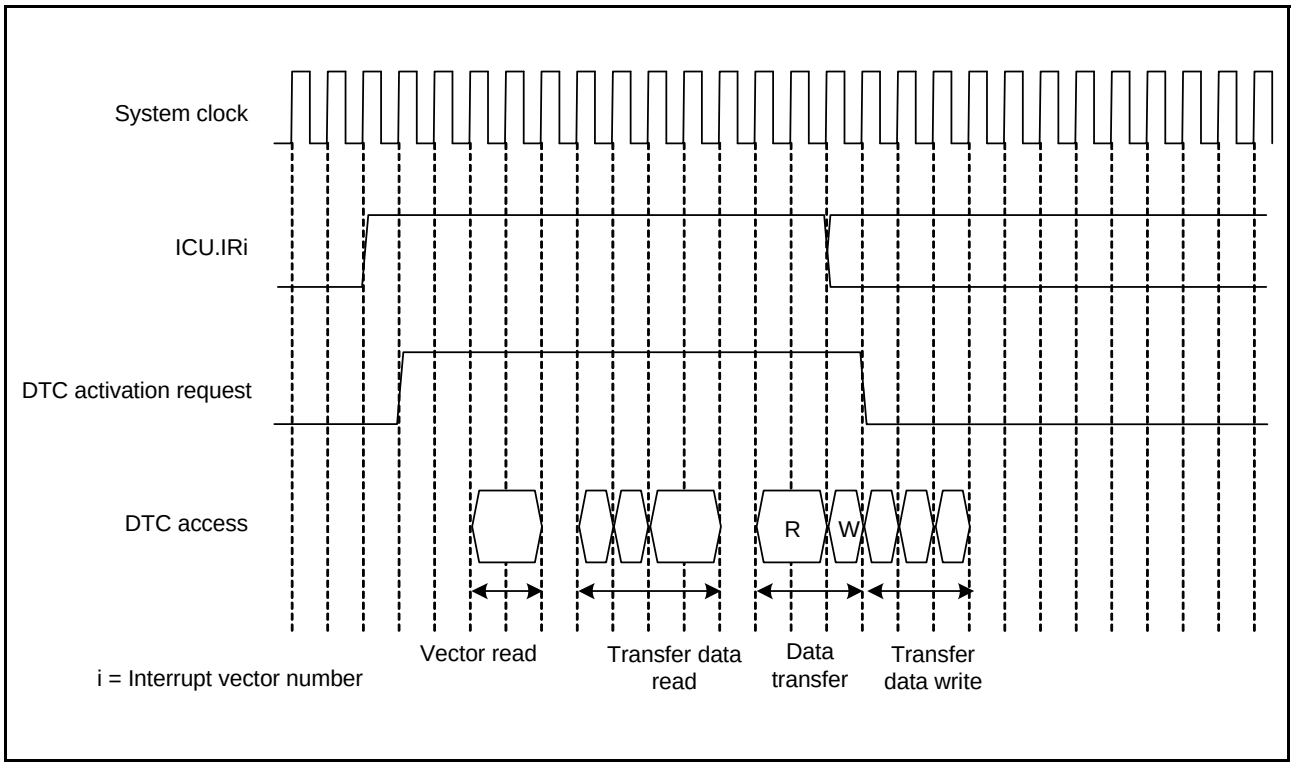


Figure 14.9 Example of DTC Operation Timing 1 (Short-Address Mode, Normal Transfer Mode, Repeat Transfer Mode)

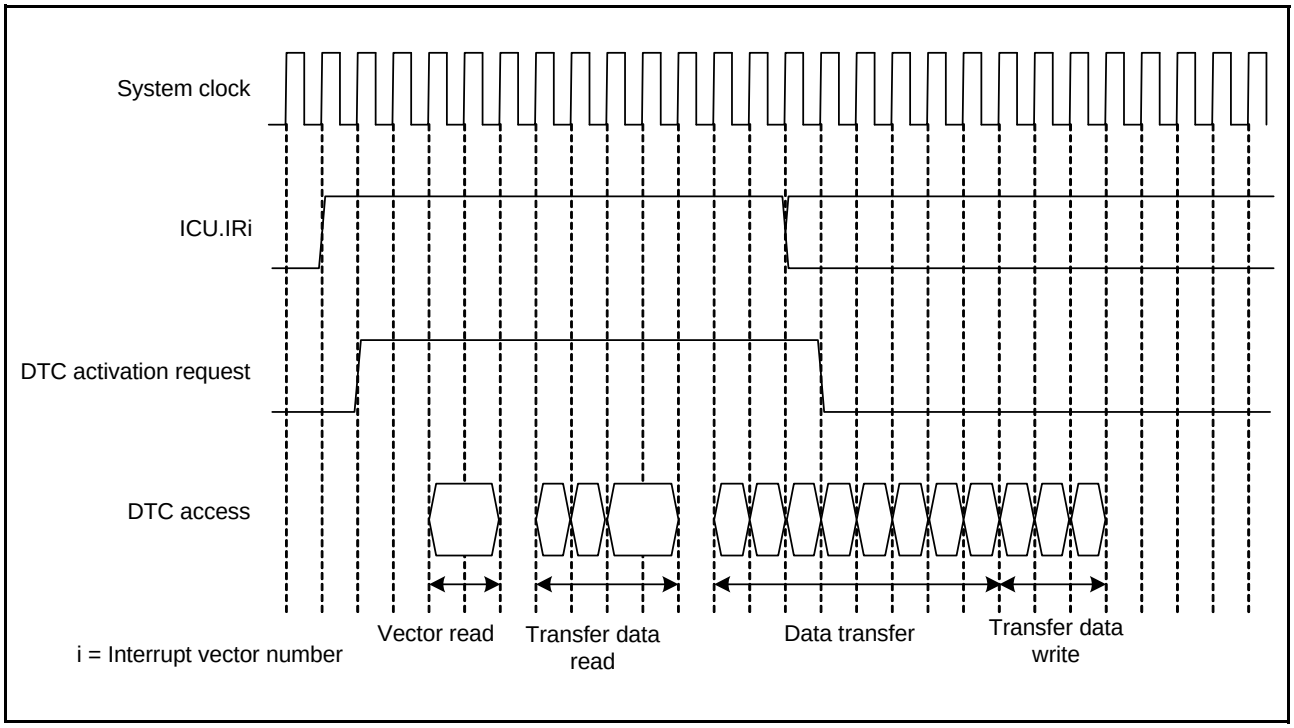


Figure 14.10 Example of DTC Operation Timing 2 (Short-Address Mode, Block Transfer Mode, Block Size = 4)

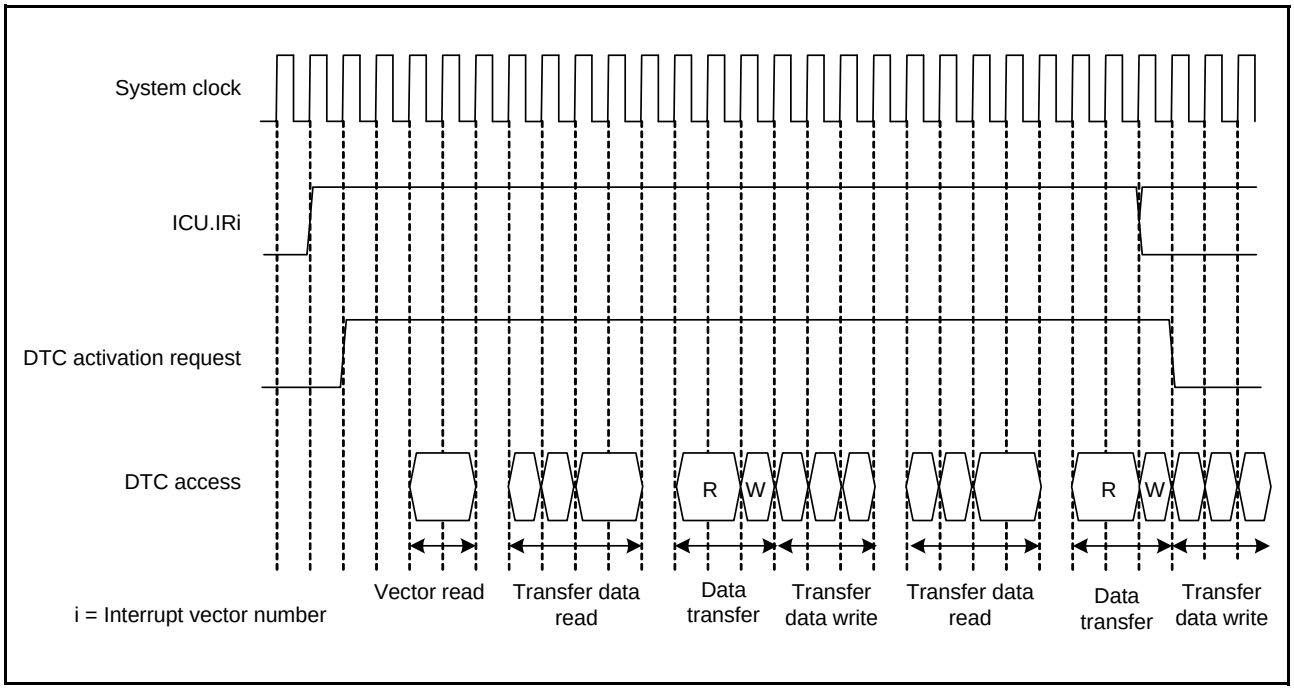


Figure 14.11 Example of DTC Operation Timing 3 (Short-Address Mode, Chain Transfer)

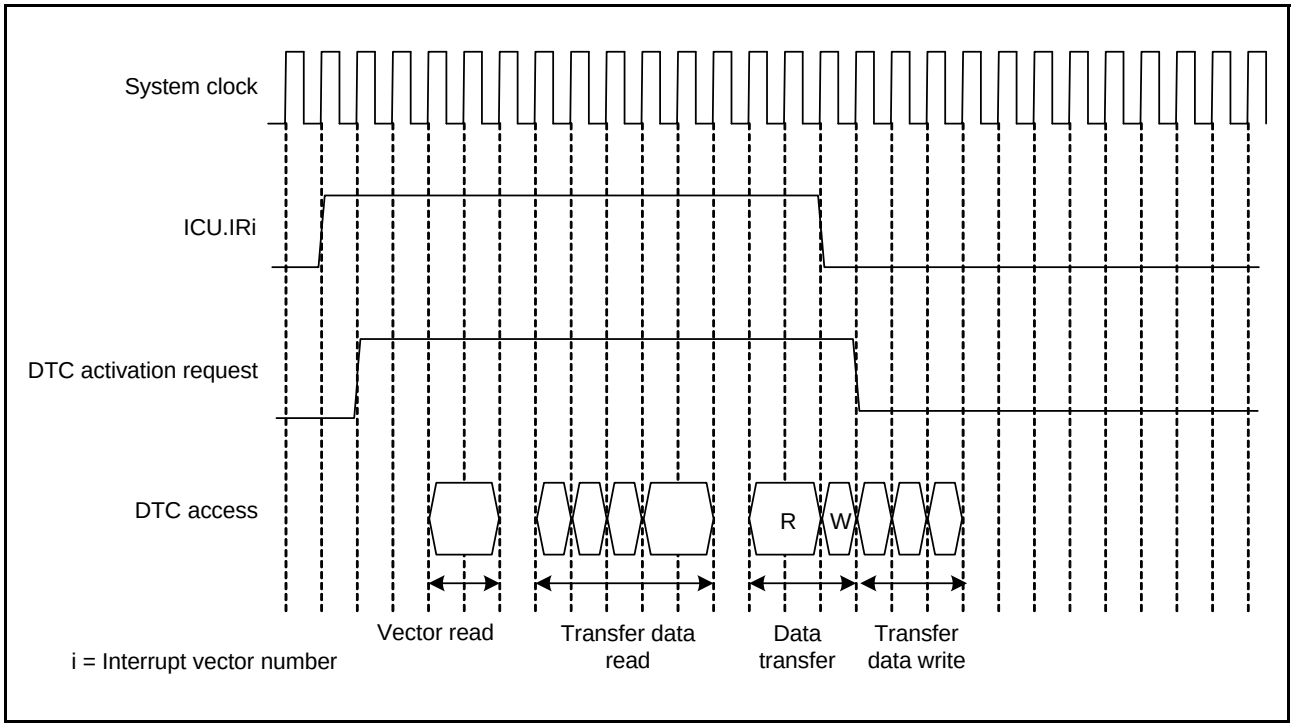
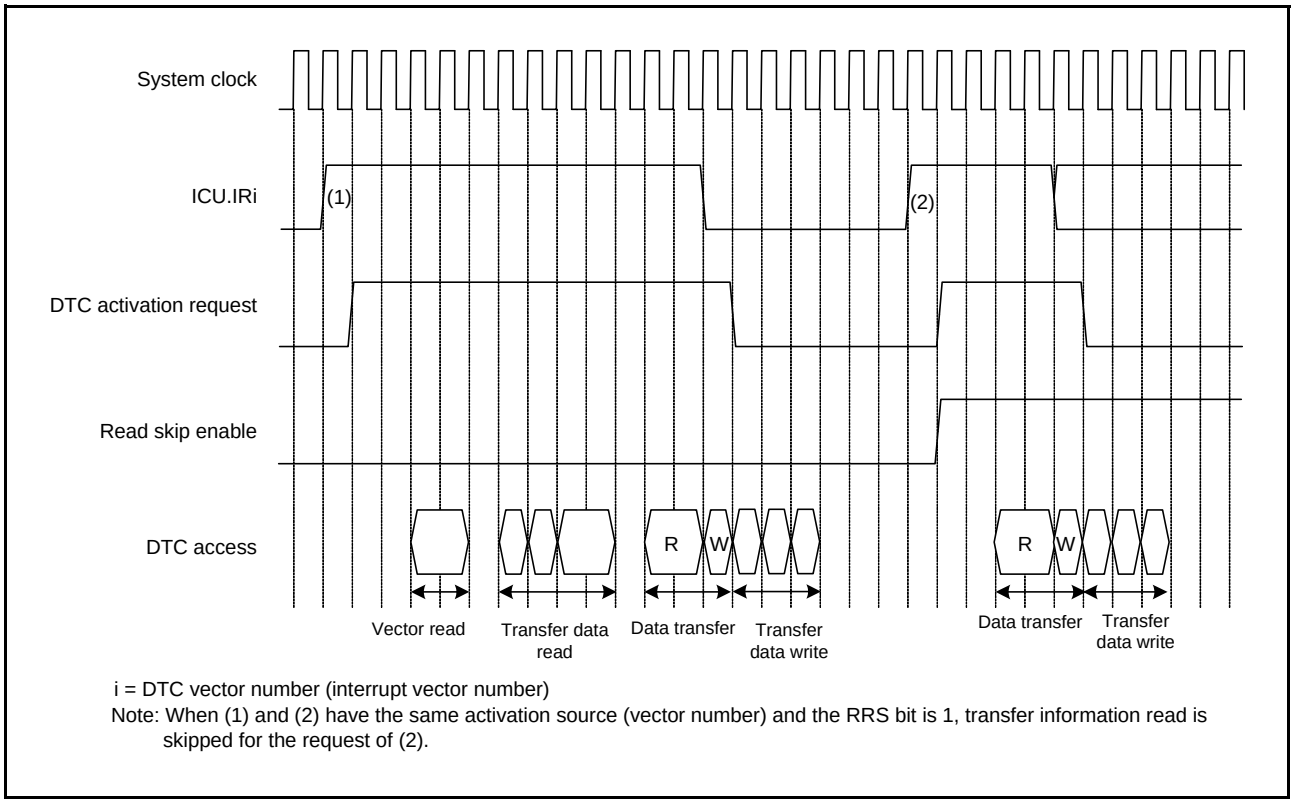


Figure 14.12 Example of DTC Operation Timing 4 (Full-Address Mode, Normal Transfer Mode, Repeat Transfer Mode)



i = DTC vector number (interrupt vector number)
Note: When (1) and (2) have the same activation source (vector number) and the RRS bit is 1, transfer information read is skipped for the request of (2).

Figure 14.13 Example of Transfer Data Read Skip

14.4.8 Execution Cycle of the DTC

Table 14.10 lists the execution cycle of single data transfer of the DTC.

Table 14.10 Execution Cycle of the DTC

Transfer Mode	Vector Read		Transfer Data Read			Transfer Data Write			Data Read	Data Write	Internal Operation	
Normal	Cv+1	0*1	4 × Ci + 1*2	3 × Ci + 1*3	0*1	3 × Ci*4	2 × Ci*5	Ci*6	Cr + 1	Cw	2	0*1
Repeat	Cv+1	0*1	4 × Ci + 1*2	3 × Ci + 1*3	0*1	3 × Ci*4	2 × Ci*5	Ci*6	Cr + 1	Cw	2	0*1
Block*7	Cv+1	0*1	4 × Ci + 1*2	3 × Ci + 1*3	0*1	3 × Ci*4	2 × Ci*5	Ci*6	P × Cr	P × Cw	2	0*1

P: Block size (set by CRAH and CRAL)
Cv: Access cycles for the vector information data storing destination
Ci: Access cycles for the transfer information data storing destination
Cr: Access cycles for the data read destination
Cw: Access cycles for the data write destination

Note 1. Transfer data skip
Note 2. Full-address mode
Note 3. Short-address mode
Note 4. When neither SAR nor DAR is set to address fixed mode
Note 5. When SAR or DAR is set to address fixed mode
Note 6. When SAR and DAR are set to address fixed mode
Note 7. These values apply when the block size is at least two. If the block size is one, the number of cycles is the same as for normal transfer.

(The unit of vector read, transfer data read, “+1” of transfer data read, and “2” of internal operation is system clock cycles (ICLK).)
(Cv, Ci, Cr, and Cw values depend on the access destination. For the number of cycles for the access destination, see section 30, RAM, section 31, ROM (Flash Memory for Code Storage), and section 5, I/O Registers.

For execution timing in each transfer mode, see section 14.4.7, Operation Timing.

14.4.9 DTC Bus Mastership Release Timing

The DTC does not release the bus mastership during transfer data read and transfer data write. While transfer data is not read or written, bus arbitration is made according to the priority determined by the bus master arbitrator.

14.5 DTC Setting Procedure

Before using the DTC, set the DTC vector base register (DTCVBR).
Follow the procedure shown in Figure 14.14 to set the DTC activation source.
Set the DTC module start bit (DTCST.DTCST) to 1.

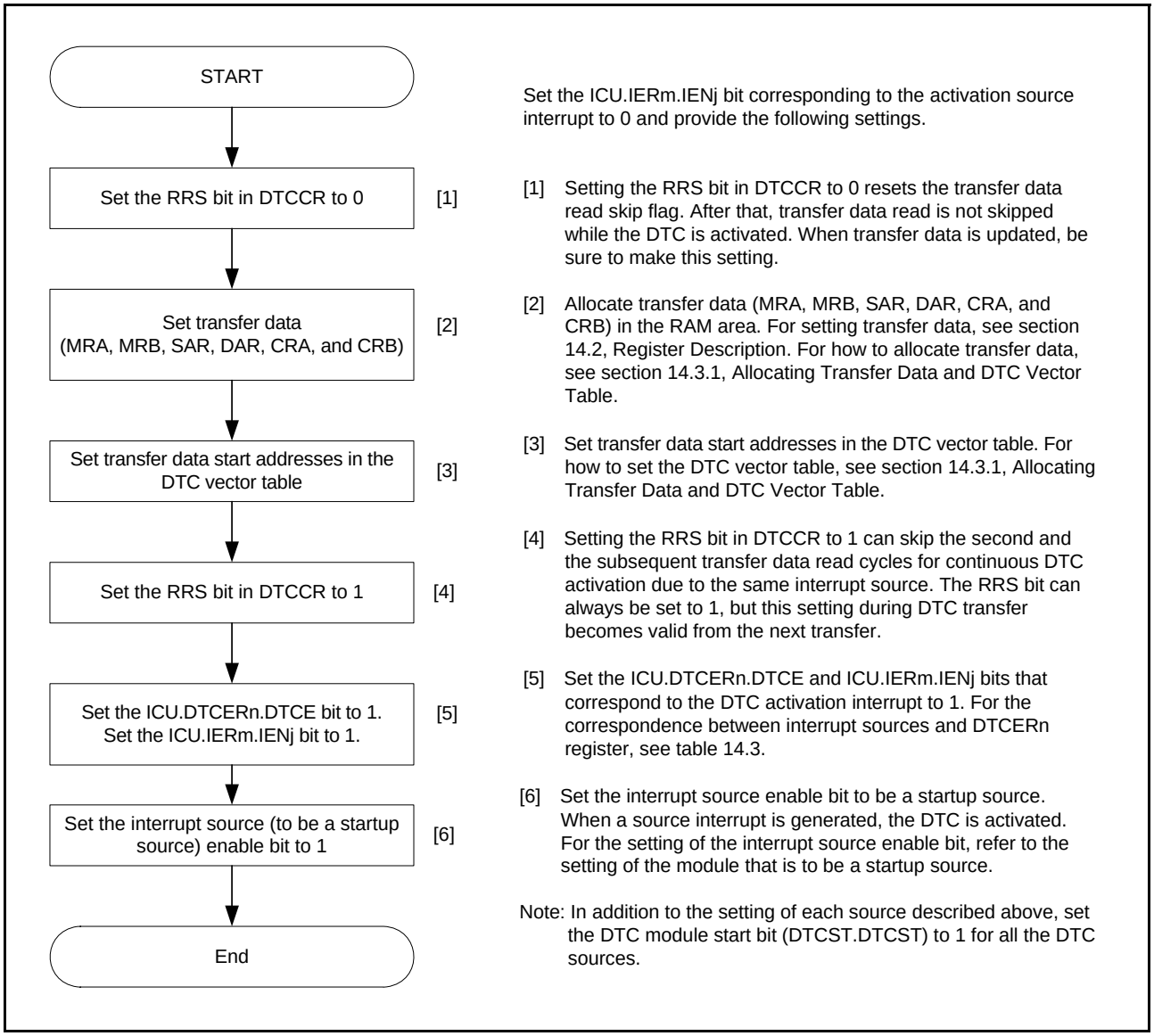


Figure 14.14 Procedure to set the DTC activation source

14.6 Examples of DTC Usage

14.6.1 Normal Transfer

As an example of DTC usage, its employment in the transfer of 128 bytes of data by an SCI is described below.

(1) Transfer Data Set

In the MRA register, make the settings to select a fixed source address (MRA.SM[1:0] = 00b), incrementation of the destination address (MRA.DM[1:0] = 10b), transfer in normal mode (MRA.MD[1:0] = 00b), and byte-sized transfer (MRA.SZ[1:0] = 00b). The MRB.DTS bit can be set to any value. For other bits of the MRB register, make the setting for one interrupt to initiate one round of transfer (MRB.CHNE = "0" and MRB.DISEL = "0"). Set the SAR to the address of the RDR for the given SCIn (n = 0 to 2), the DAR to the first address of the area in RAM where data are to be stored, and the CRA register to 128 (0080h). The CRB register can be set to any value. Set a value of FFFFh to the CRB.

(2) DTC Vector Table

The address where the transfer-control information for use with the RXI starts is set in the vector table for the DTC.

(3) ICU Set and DTC Module Activation

Set the corresponding ICU.DTCERn.DTCE bit to "1" and the ICU.IERm.IENj bit to "1".
Set the DTCST.DTCST bit to "1".

(4) SCI Set

Enable reception-completed interrupts by setting the SCR.RIE bit in the given SCIn to "1". Also, so that further reception does not proceed if a reception error occurs while reception by the SCI is in progress, make the CPU able to accept reception-error interrupts.

(5) DTC Transfer

Every time the reception of one byte by the SCI is completed, an RXI interrupt is generated to activate the DTC. The DTC transfers the received byte from the RDR of the SCI to RAM, after which the DAR register is incremented and the CRA register is decremented.

(6) Interrupt Handling

After 128 rounds of data transfer have been completed and the value in the CRA register becomes "0", an RXI interrupt request is generated for the CPU. Processing for completion is performed in the processing routine for this interrupt.

14.6.2 Chain Transfer when Counter = 0

The second data transfer is performed only when the counter = 0. Repeat transfer of a transfer count of 256 or more is enabled by the re-setting for the first data transfer.

The following shows an example of configuring a 128-kbyte input buffer, where the input buffer is set so that its lower address starts with 0000h. Figure 14.15 shows a chain transfer when the counter = 0.

1. Set normal transfer mode for input data for the first data transfer. Set the following:
   Transfer source address: Fixed, CRA = 0000h (65,536 times), CHNE bit = 1 (chain transfer enabled) in MRB, CHNS bit = 1 (chain transfer is performed only when the transfer counter is 0) in MRB, and DISEL bit = 0 (an interrupt request to the CPU is generated when specified data transfer is completed) in MRB.
2. Prepare the upper 8-bit address of the start address at every 65,536 times of the transfer destination address for the first data transfer in another area (such as ROM). For example, when setting the input buffer to 200000h to 21FFFFh, prepare 21h and 20h.
3. For the second data transfer, set repeat transfer mode (source side: repeat area) for re-setting the transfer destination address of the first data transfer. Specify the upper 8 bits of DAR in the first transfer data area for the transfer destination. At this time, set CHNE bit = 0 (chain transfer disabled) in MRB and DISEL bit = 0 (an interrupt request to the CPU is generated when specified data transfer is completed) in MRB. When setting the input buffer mentioned above to 200000h to 21FFFFh, set the transfer counter to 2.
4. The first data transfer is performed by an interrupt 65,536 times. When the transfer counter of the first data transfer becomes 0, the second data transfer starts. Set the upper 8 bits of the transfer source address of the first data transfer to 21h. The transfer counter (lower 16 bits) of the transfer destination address of the first data transfer is 0000h.
5. In succession, the first data transfer is performed by an interrupt 65,536 times specified for the first data transfer. When the transfer counter of the first data transfer becomes 0, the second data transfer starts. Set the upper 8 bits of the transfer source address of the first data transfer to 20h. The transfer counter (lower 16 bits) of the transfer destination address of the first data transfer is 0000h.
6. Steps 4 and 5 above are repeated infinitely. Since the second data transfer is in repeat transfer mode, no interrupt request to the CPU is generated

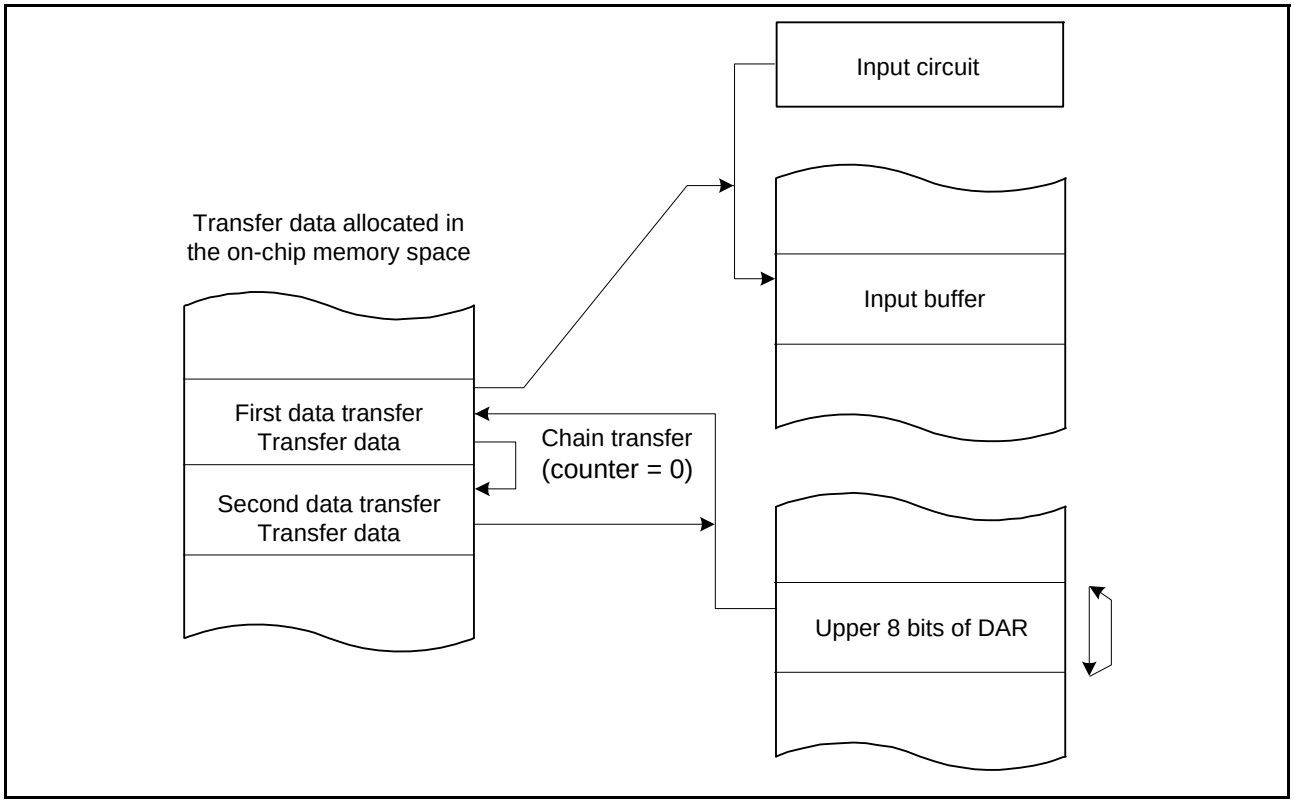


Figure 14.15 Chain Transfer when Counter = 0

14.7 Interrupt Source

When the DTC has finished data transfer of specified count or when data transfer with the DISEL bit in MRB set to 1 (an interrupt request to the CPU is generated each time DTC data transfer is performed) has been completed, an interrupt to the CPU is generated by the DTC activation source. Such interrupts to the CPU are controlled according to the PSW.I bit (interrupt enable) and the PSW.IPL[3:0] bits (processor interrupt priority level) of the CPU, and the priority level of the interrupt controller.

14.8 Low-Power Consumption Function

To place the DTC in the module-stop state, all-module clock stop mode, software-standby mode, or deep software-standby mode, clear the DTCST.DTCST bit to 0 (DTC module stopped), and then perform the following processing.

(1) Module Stop Function

Writing 1 to the MSTPCRA.MSTPA28 bit (transition to the DTC module-stop state) enables the module-stop function of the DTC. If DTC transfer is in progress at the time a 1 is written to the MSTPA28 bit, the transition to the module-stop state proceeds after DTC transfer has ended. Writing 0 to the MSTPA28 bit releases the DTC from the module-stop state.

(2) All-Module Clock Stop Mode

Writing 1 to the MSTPCRA.ACSE bit (all-module clock stop mode enabled), writing 1 to all the bits in MSTPCRA and MSTPCRB, including the MSTPA28 bit (transition to the DTC module-stop state), and executing a WAIT instruction causes a transition to the all-module clock stop mode. If DTC transfer is in progress at the time the WAIT instruction is executed, the DTC can enter all-module clock stop mode after completion of the current DTC transfer.
After the DTC returns from all-module clock stop mode, writing 0 to the MSTPA28 bit releases the DTC from the module-stop state.

(3) Software Standby and Deep Software Standby Modes

Writing 1 to the SBYCR.SSBY bit (transition to software standby mode after WAIT instruction execution) and 0 to the DPSBYCR.DPSBY bit (transition to software standby mode after WAIT instruction execution), executing a WAIT instruction places the DTC in software standby mode.
If DTC transfer is in progress at the time the WAIT instruction is executed, the DTC enters software standby mode after completion of the current DTC transfer.
The DTC enters deep software standby mode when the DPSBYCR.DPSBY bit is set to 1 (transition to deep software standby mode after WAIT instruction execution) and then a WAIT instruction is executed.

(4) Notes on Low-Power Consumption Function

For the timing of WAIT instruction execution and register settings, see section 9.6.7, Timing of Wait Instructions.
To perform DTC transfer after returning from low-power consumption mode, set the DTCST.DTCST bit to 1 again.

14.9 Usage Notes

14.9.1 Transfer Information Data Start Address

Be sure to set multiples of 4 for the transfer information data start addresses in the DTC vector table. Otherwise, such addresses are accessed with their lowest 2 bits regarded as 00b.

14.9.2 Allocating Transfer Data

Allocate transfer data in the memory area according to the endian of the area as shown in Figure 14.16.
For example, when writing CRA and CRB setting data with 16 bits in big endian, write the CRA setting data to lower address 0 and the CRB setting data to lower address 2. In little endian, write the CRB setting data to lower address 0 and the CRA setting data to lower address 2. When writing CRA and CRB setting data with 32 bits, place the CRA setting data at the MSB side and the CRB setting data at the LSB side regardless of endian, and then write the data to lower address 0.

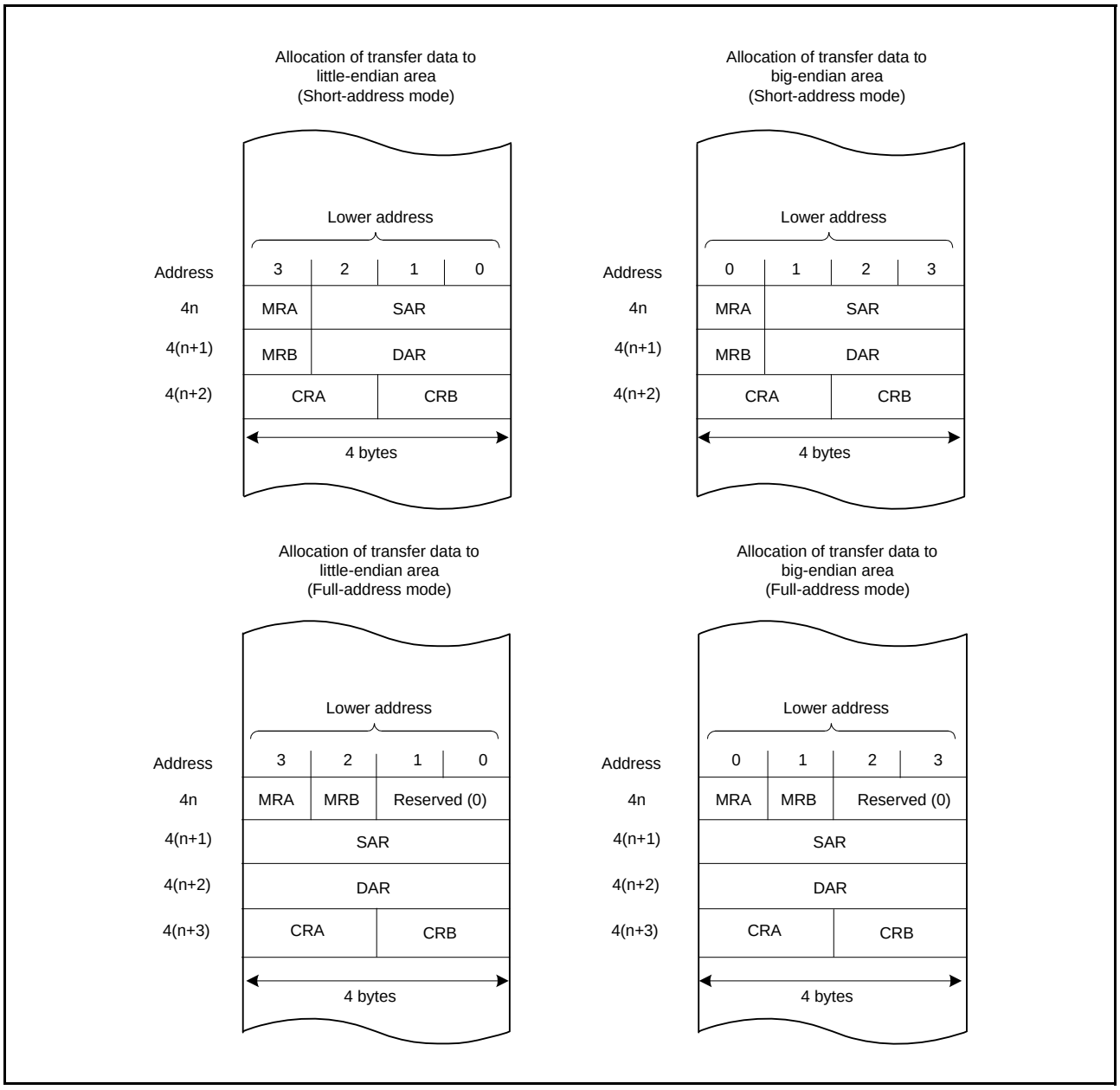


Figure 14.16 Allocation of Transfer Data

14.9.3 Setting the DTC Activation Enable Register (ICU.DTCERn) of the Interrupt Controller

While the DTCST.DTCST bit is 0 (DTC module stop), set the interrupt destination setting register n (ISELRn) of the ICU. For details on the ICU.DTCERn registers, refer to section 11, Interrupt Controller (ICU).

14.9.4 Selecting Communication Function Interrupt as DTC Activation Source

In the RX62T Groups, caution should be used when the communication function (SCI, RIIC, RSPI) is used in combination with the DTC function. For details, section 11.7, Usage Notes.

15. I/O Ports

The I/O ports of the RX62T Group function as a programmable I/O port, an I/O pin of a peripheral module, an input pin for an interrupt, or a bus control pin.
Each pin is also configurable as an I/O pin of a peripheral module or an input pin for an interrupt. All pins function as input pins immediately after a reset, and pin functions are switched by register settings. The setting of each pin is specified by the registers for the corresponding I/O port and peripheral modules.
Each port has data direction registers (DDR) that control input and output, data registers (DR) that store data for output, port registers (PORT) for reading the pin states, and input buffer control registers (ICR) that enable or disable the input buffer.
As the configuration of the I/O ports differs with the package, the I/O ports for the respective packages are described separately in this section.
For the 112-pin LQFP version, see section I/O Ports [for 112-Pin LQFP], I/O Ports [for 112-Pin LQFP].
For the 100-pin LQFP versions, see section I/O Port [for 100-Pin LQFP], I/O Port [for 100-Pin LQFP].
For the 80-pin LQFP version, see section I/O Port [for 80-Pin LQFP].
For the 64-pin LQFP version, see section I/O Port [for 64-Pin LQFP].

15.1 I/O Ports [for 112-Pin LQFP]

The RX62T Group (112-Pin LQFP) has 14 I/O ports (ports 1 to 9 and A, B, D, E, G), which handle 61 I/O pins.

15.1.1 Overview

Table 15.1 gives the specifications of the I/O ports and Table 15.2 lists I/O ports and pin functions.

Table 15.1 Specifications of I/O Ports (112-Pin LQFP)

Item	Description
I/O pins	61
Input pins	21
Number of ports	14 (1 to 9 and A, B, D, E, and G)
Open drain outputs	2 (RIIC pin)
Large-current output	12 (MTU3 pin and GPT pin)
Schmitt trigger input pins	All port inputs, CAN inputs, IRQ inputs, MTU3 inputs, POE3 inputs, RIIC inputs, SCI inputs, A/D trigger inputs, NMI inputs, GPT inputs, and LIN inputs
Others	Each pin is capable of driving a capacitive load of 30 pF in the case of a TTL load. When configured as an output, a pin is capable of driving a Darlington transistor. A pin is always capable of reading the status of the pins.

Table 15.2 Port Functions (112-Pin LQFP) (1 / 4)

Port	Description	Bit	Function			CMOS Input	Schmitt Trigger Input	Open Drain Output Capability	Large-Current Output
			I/O	Input	Output				
Port 1	General I/O port pins, MTU3 Inputs, and interrupt inputs	0	P10	MTCLKD-B/ IRQ0-A		—	All input functions	—	—
		1	P11	MTCLKC-B/ IRQ1-A			All input functions		
Port 2	General I/O port pins, MTU3 inputs, interrupt inputs, A/D converter inputs, RSPI I/O signal, LIN I/O signal, and CAN I/O signals	0	P20	MTCLKB-B/ IRQ7/ ADTRG0#-B		—	All input functions	—	—
		1	P21	MTCLKA-B/ IRQ6/ ADTRG1#-B			All input functions		
		2	P22/MISO-A	LRX/CRX-B/ ADTRG#		MISO-A	P22/LRX/ CRX-B/ ADTRG#		
		3	P23/MOSI-A		LTX/ CTX-B	MOSI-A	P23		
		4	P24/RSPCK-A			RSPCK-A	P24		
Port 3	General I/O port pins, MTU3 I/O signal, and RSPI I/O signal	0	P30/ MTIOC0B-B/ SSL0-A	MTCLKD-A		SSL0-A	P30/ MTIOC0B-B/ MTCLKD-A	—	—
		1	P31/ MTIOC0A-B	MTCLKC-A	SSL1-A	—	All input functions		
		2	P32/MTIOC3C	MTCLKB-A	SSL2-A		All input functions		
		3	P33/MTIOC3A	MTCLKA-A	SSL3-A		All input functions		
Port 4	A/D converter inputs and general input port pins	0		P40/AN000		—	P40	—	—
		1		P41/AN001			P41		
		2		P42/AN002			P42		
		3		P43/AN003/ CVREFL			P43		
		4		P44/AN100			P44		
		5		P45/AN101			P45		
		6		P46/AN102			P46		
		7		P47/AN103/ CVREFH			P47		
Port 5	A/D converter inputs and general input port pins	0		P50/AN6		—	P50	—	—
		1		P51/AN7			P51		
		2		P52/AN8			P52		
		3		P53/AN9			P53		
		4		P54/AN10			P54		
		5		P55/AN11			P55		
Port 6	A/D converter inputs and general input port pins	0		P60/AN0		—	P60	—	—
		1		P61/AN1			P61		
		2		P62/AN2			P62		
		3		P63/AN3			P63		
		4		P64/AN4			P64		
		5		P65/AN5			P65		

Table 15.2 Port Functions (112-Pin LQFP) (2 / 4)

Port	Description	Bit	Function			CMOS Input	Schmitt Trigger Input	Open Drain Output Capability	Large-Current Output
			I/O	Input	Output				
Port 7	General I/O port pins, POE3 Inputs, interrupt inputs, MTU3 I/O signal, and GPT I/O signal	0	P70	POE0#/IRQ5		—	All input functions	—	—
		1	P71/ MTIOC3B/ GTIOC0A-A				All input functions		√
		2	P72/ MTIOC4A/ GTIOC1A-A				All input functions		√
		3	P73/ MTIOC4B/ GTIOC2A-A				All input functions		√
		4	P74/ MTIOC3D/ GTIOC0B-A				All input functions		√
		5	P75/ MTIOC4C/ GTIOC1B-A				All input functions		√
		6	P76/ MTIOC4D/ GTIOC2B-A				All input functions		√
Port 8	General I/O port pins, SCI I/O signal and MTU3 inputs	0	P80	RXD2-B/ MTIC5W		—	All input functions	—	—
		1	P81	MTIC5V	TXD2-B		All input functions		
		2	P82/SCK2-B	MTIC5U			All input functions		
Port 9	General I/O port pins, MTU3 I/O signal, POE3 inputs, and interrupt inputs	0	P90/MTIOC7D			—	All input functions	—	√
		1	P91/MTIOC7C				All input functions		√
		2	P92/MTIOC6D				All input functions		√
		3	P93/MTIOC7B				All input functions		√
		4	P94/MTIOC7A				All input functions		√
		5	P95/MTIOC6B				All input functions		√
		6	P96	POE4#/IRQ4			All input functions		—

Table 15.2 Port Functions (112-Pin LQFP) (3 / 4)

Port	Description	Bit	Function			CMOS Input	Schmitt Trigger Input	Open Drain Output Capability	Large-Current Output
			I/O	Input	Output				
Port A	General I/O port pins, MTU3 I/O signal, RSPI I/O signal, and A/D converter inputs	0	PA0/ MTIOC6C		SSL3-B	—	All input functions	—	—
		1	PA1/MTIOC6A		SSL2-B		All input functions		
		2	PA2/MTIOC2B		SSL1-B		All input functions		
		3	PA3/ MTIOC2A/ SSL0-B			SSL0-B	PA3/ MTIOC2A		
		4	PA4/ MTIOC1B/ RSPCK-B	ADTRG0#-A		RSPCK-B	PA4/ MTIOC1B/ ADTRG0#-A		
		5	PA5/ MTIOC1A/ MISO-B	ADTRG1#-A		MISO-B	PA5/ MTIOC1A/ ADTRG1#-A		
Port B	General I/O port pins, MTU3 I/O signal, RSPI I/O signal, RIIC I/O signal, SCI I/O signal, GPT inputs, POE3 inputs, interrupt inputs, and CAN I/O signal	0	PB0/ MTIOC0D/ MOSI-B			MOSI-B	PB0/ MTIOC0D	—	—
		1	PB1/ MTIOC0C/ SCL	RXD0		—	All input functions	√ (SCL only)	—
		2	PB2/ MTIOC0B-A/ SDA		TXD0		All input functions	√ (SDA only)	—
		3	PB3/ MTIOC0A-A/ SCK0				All input functions	—	—
		4	PB4	GTETRG/ POE8#/IRQ3			All input functions		
		5	PB5		TXD2-A/ CTX-A/		All input functions		
		6	PB6	RXD2-A/ CRX-A			All input functions		
		7	PB7/SCK2-A				All input functions		

Table 15.2 Port Functions (112-Pin LQFP) (4 / 4)

Port	Description	Bit	Function			CMOS Input	Schmitt Trigger Input	Open Drain Output Capability	Large-Current Output
			I/O	Input	Output				
Port D	General I/O port pins, GPT I/O signal, RSPI I/O signal, SCI I/O signal, and CAN outputs	0	PD0/ GTIOC3B/ RSPCK-C			RSPCK-C	PD0/ GTIOC3B	—	—
		1	PD1/ GTIOC3A/ MISO-C			MISO-C	PD1/ GTIOC3A		
		2	PD2/ GTIOC2B-B/ MOSI-C			MOSI-C	PD2/ GTIOC2B-B		
		3	PD3/ GTIOC2A-B		TXD1	—	All input functions		
		4	PD4/ GTIOC1B-B/ SCK1				All input functions		
		5	PD5/ GTIOC1A-B	RXD1		—	All input functions		
		6	PD6/ GTIOC0B-B/ SSL0-C			SSL0-C	PD6/ GTIOC0B-B		
		7	PD7/ GTIOC0A-B		SSL1-C/ CTX-C	—	All input functions		
Port E	General I/O port pins, CAN inputs, RSPI outputs, POE3 inputs, MTU3 inputs, and interrupt inputs	0	PE0	CRX-C	SSL2-C	—	All input functions	—	—
		1	PE1		SSL3-C		All input functions		
		2		PE2/ POE10#-A/ NMI			All input functions		
		3	PE3	MTCLKD-C/ POE11#/ IRQ2-A			All input functions		
		4	PE4	MTCLKC-C/ POE10#-B/ IRQ1-B			All input functions		
		5	PE5	IRQ0-B			All input functions		
Port G	General I/O port pins, interrupt inputs, and trace outputs	0	PG0	IRQ0-C	TRSYNC	—	All input functions	—	—
		1	PG1	IRQ1-C	TRDATA 0		All input functions		
		2	PG2	IRQ2-B	TRDATA 1		All input functions		
		3	PG3		TRDATA 2		All input functions		
		4	PG4		TRDATA 3		All input functions		
		5	PG5		TRCLK		All input functions		

15.1.2 Register Descriptions

Table 15.3 lists registers of I/O ports, and Table 15.4 lists valid bits in each register.

Table 15.3 Registers of I/O Ports (112-Pin LQFP) (1 / 2)

Port Symbol	Register Name	Register Symbol	Value after Reset	Address	Access Size
PORT1	Data direction register	DDR	00h	0008 C001h	8
	Data register	DR	00h	0008 C021h	8
	Port register	PORT	Undefined	0008 C041h	8
	Input buffer control register	ICR	00h	0008 C061h	8
PORT2	Data direction register	DDR	00h	0008 C002h	8
	Data register	DR	00h	0008 C022h	8
	Port register	PORT	Undefined	0008 C042h	8
	Input buffer control register	ICR	00h	0008 C062h	8
PORT3	Data direction register	DDR	00h	0008 C003h	8
	Data register	DR	00h	0008 C023h	8
	Port register	PORT	Undefined	0008 C043h	8
	Input buffer control register	ICR	00h	0008 C063h	8
PORT4	Port register	PORT	Undefined	0008 C044h	8
	Input buffer control register	ICR	00h	0008 C064h	8
PORT5	Port register	PORT	Undefined	0008 C045h	8
	Input buffer control register	ICR	00h	0008 C065h	8
PORT6	Port register	PORT	Undefined	0008 C046h	8
	Input buffer control register	ICR	00h	0008 C066h	8
PORT7	Data direction register	DDR	00h	0008 C007h	8
	Data register	DR	00h	0008 C027h	8
	Port register	PORT	Undefined	0008 C047h	8
	Input buffer control register	ICR	00h	0008 C067h	8
PORT8	Data direction register	DDR	00h	0008 C008h	8
	Data register	DR	00h	0008 C028h	8
	Port register	PORT	Undefined	0008 C048h	8
	Input buffer control register	ICR	00h	0008 C068h	8
PORT9	Data direction register	DDR	00h	0008 C009h	8
	Data register	DR	00h	0008 C029h	8
	Port register	PORT	Undefined	0008 C049h	8
	Input buffer control register	ICR	00h	0008 C069h	8
PORTA	Data direction register	DDR	00h	0008 C00Ah	8
	Data register	DR	00h	0008 C02Ah	8
	Port register	PORT	Undefined	0008 C04Ah	8
	Input buffer control register	ICR	00h	0008 C06Ah	8
PORTB	Data direction register	DDR	00h	0008 C00Bh	8
	Data register	DR	00h	0008 C02Bh	8
	Port register	PORT	Undefined	0008 C04Bh	8
	Input buffer control register	ICR	00h	0008 C06Bh	8
PORTD	Data direction register	DDR	00h	0008 C00Dh	8
	Data register	DR	00h	0008 C02Dh	8
	Port register	PORT	Undefined	0008 C04Dh	8
	Input buffer control register	ICR	00h	0008 C06Dh	8

Table 15.3 Registers of I/O Ports (112-Pin LQFP) (2 / 2)

Port Symbol	Register Name	Register Symbol	Value after Reset	Address	Access Size
PORTE	Data direction register	DDR	00h	0008 C00Eh	8
	Data register	DR	00h	0008 C02Eh	8
	Port register	PORT	Undefined	0008 C04Eh	8
	Input buffer control register	ICR	00h	0008 C06Eh	8
PORTG	Data direction register	DDR	00h	0008 C010h	8
	Data register	DR	00h	0008 C030h	8
	Port register	PORT	Undefined	0008 C050h	8
	Input buffer control register	ICR	00h	0008 C070h	8
IOPORT	Port function register 8	PF8IRQ	00h	0008 C108h	8
	Port function register 9	PF9IRQ	00h	0008 C109h	8
	Port function register A	PFAADC	00h	0008 C10Ah	8
	Port function register C	PFCMTU	00h	0008 C10Ch	8
	Port function register D	PFDGPT	00h	0008 C10Dh	8
	Port function register F	PFFSCI	00h	0008 C10Fh	8
	Port function register G	PFGSPI	00h	0008 C110h	8
	Port function register H	PFHSPI	00h	0008 C111h	8
	Port function register J	PFJCAN	00h	0008 C113h	8
	Port function register K	PFKLIN	00h	0008 C114h	8
	Port function register M	PFMPOE	00h	0008 C116h	8
	Port function register N	PFNPOE	00h	0008 C117h	8

Table 15.4 Valid Bits in Each Register (112-Pin LQFP) (1 / 2)

Register Symbol	b7	b6	b5	b4	b3	b2	b1	b0
PORT1.DDR	x	x	x	x	x	x	√	√
PORT2.DDR	x	x	x	√	√	√	√	√
PORT3.DDR	x	x	x	x	√	√	√	√
PORT7.DDR	x	√	√	√	√	√	√	√
PORT8.DDR	x	x	x	x	x	√	√	√
PORT9.DDR	x	√	√	√	√	√	√	√
PORTA.DDR	x	x	√	√	√	√	√	√
PORTB.DDR	√	√	√	√	√	√	√	√
PORTD.DDR	√	√	√	√	√	√	√	√
PORTE.DDR	x	x	√	√	√	x	√	√
PORTG.DDR	x	x	√	√	√	√	√	√
PORT1.DR	x	x	x	x	x	x	√	√
PORT2.DR	x	x	x	√	√	√	√	√
PORT3.DR	x	x	x	x	√	√	√	√
PORT7.DR	x	√	√	√	√	√	√	√
PORT8.DR	x	x	x	x	x	√	√	√
PORT9.DR	x	√	√	√	√	√	√	√
PORTA.DR	x	x	√	√	√	√	√	√
PORTB.DR	√	√	√	√	√	√	√	√
PORTD.DR	√	√	√	√	√	√	√	√
PORTE.DR	x	x	√	√	√	x	√	√
PORTG.DR	x	x	√	√	√	√	√	√
PORT1.PORT	x	x	x	x	x	x	√	√
PORT2.PORT	x	x	x	√	√	√	√	√
PORT3.PORT	x	x	x	x	√	√	√	√
PORT4.PORT	√	√	√	√	√	√	√	√
PORT5.PORT	x	x	√	√	√√	√	√	√
PORT6.PORT	x	x	√	√	√	√	√	√
PORT7.PORT	x	√	√	√	√	√	√	√
PORT8.PORT	x	x	x	x	√	√	√	√
PORT9.PORT	x	√	√	√	√	√	√	√
PORTA.PORT	x	x	√	√	√	√	√	√
PORTB.PORT	√	√	√	√	√	√	√	√
PORTD.PORT	√√	√	√	√	√√	√	√	√
PORTE.PORT	x	x	√	√√	√	√	√	√
PORTG.PORT	x	x	√	√	√	√	√	√
PORT1.ICR	x	x	x	x	x	x	√	√
PORT2.ICR	x	x	x	√	√	√	√	√
PORT3.ICR	x	x	x	x	√	√	√	√
PORT4.ICR	√	√	√	√	√	√	√√	√
PORT5.ICR	x	x	√	√	√	√	√	√
PORT6.ICR	x	x	√	√	√	√	√	√
PORT7.ICR	x	√	√	√	√	√√	√	√
PORT8.ICR	x	x	x	x	x	√	√	√

Table 15.4 Valid Bits in Each Register (112-Pin LQFP) (2 / 2)

Register Symbol	b7	b6	b5	b4	b3	b2	b1	b0
PORT9.ICR	x	√	√	√	√	√	√	√
PORTA.ICR	x	x	√	√	√	√	√	√
PORTB.ICR	√	√	√	√	√	√	√	√
PORTD.ICR	√	√	√	√	√	√	√	√
PORTE.ICR	x	x	√	√	√√	x	√	√
PORTG.ICR	x	x	√	√	√	√	√	√
IOPORT.PF8IRQ	x	x	x	x	√	√	√	√
IOPORT.PF9IRQ	x	x	x	x	x	√	x	x
IOPORT.PFAADC	x	x	x	x	x	x	√	√
IOPORT.PFCMTU	√	√	x	x	x	x	√	√
IOPORT.PFDGPT	x	x	x	x	x	x	x	√
IOPORT.PFFSCI	x	x	x	x	x	√	x	x
IOPORT.PFGSPI	√	√	√	√	√	√	√	x
IOPORT.PFHSPI	x	x	x	x	x	x	√	√
IOPORT.PFJCAN	√	√	x	x	x	x	x	√
IOPORT.PFKLIN	x	x	x	x	x	x	x	√
IOPORT.PFMPOE	x	x	x	√	√	√	√	√
IOPORT.PFNPOE	√	x	x	x	x	x	x	x

√: Enabled bit, x: Disabled bit (Reserved)

15.1.2.1 Data Direction Register (DDR)

Address: PORT1.DDR 0008 C001h, PORT2.DDR 0008 C002h, PORT3.DDR 0008 C003h,PORT7.DDR 0008 C007h, PORT8.DDR 0008 C008h, PORT9.DDR 0008 C009h, PORTA.DDR 0008 C00Ah, PORTB.DDR 0008 C00Bh, PORTD.DDR 0008 C00Dh, PORTE.DDR 0008 C00Eh, PORTG.DDR 0008 C010h

	b7	b6	b5	b4	b3	b2	b1	b0
	B7	B6	B5	B4	B3	B2	B1	B0
Value after reset:	0	0	0	0	0	0	0	0

Notes:

1. The lower two bits are valid and the upper six bits are reserved in PORT1.DDR.
   The lower five bits are valid and the upper three bits are reserved in PORT2.DDR.
   The lower four bits are valid and the upper four bits are reserved in PORT3.DDR.
   The lower seven bits are valid and the highest order bit is reserved in PORT7.DDR.
   The lower three bits are valid and the upper five bits are reserved in PORT8.DDR.
   The lower seven bits are valid and the highest order bit is reserved in PORT9.DDR.
   The lower six bits are valid and the upper two bits are reserved inPORTA.DDR.
   Bit 5 to bit 3, bit 1, and bit 0 are valid and bit 7, bit 6, and bit 2 are reserved in PORTE.DDR.
   The lower six bits are valid and the upper two bits are reserved in PORTG.DDR.
2. The reserved bits are read as 0. The write value should always be 0.

Bit	Symbol	Bit Name	Description	R/W
b0	B0	Pn0 I/O Select (n = 1 to 3, 7 to 9, A, B, D, E, G)	0: An input pin 1: An output pin	R/W
b1	B1	Pn1 I/O Select		R/W
b2	B2	Pn2 I/O Select		R/W
b3	B3	Pn3 I/O Select		R/W
b4	B4	Pn4 I/O Select		R/W
b5	B5	Pn5 I/O Select		R/W
b6	B6	Pn6 I/O Select		R/W
b7	B7	Pn7 I/O Select		R/W

n = 1 to 3, 7 to 9, A, B, D, E, G

Each PORTn.DDR is used to select the input or output direction for individual pins of the corresponding port that have been configured to function as general I/O pins.
Each bit of a PORTn.DDR (n = 1 to 3, 7 to 9, A, B, D, E, G) corresponds to a pin of Pn, and the settings can change from bit to bit.

15.1.2.2 Data Register (DR)

Address: PORT1.DR 0008 C021h, PORT2.DR 0008 C022h, PORT3.DR 0008 C023h, PORT7.DR 0008 C027h, PORT8.DR 0008 C028h, PORT9.DR 0008 C029h, PORTA.DR 0008 C02Ah, PORTB.DR 0008 C02Bh, PORTD.DR 0008 C02Dh, PORTE.DR 0008 C02Eh, PORTG.DR 0008 C030h

	b7	b6	b5	b4	b3	b2	b1	b0
	B7	B6	B5	B4	B3	B2	B1	B0
Value after reset:	0	0	0	0	0	0	0	0

Notes:

1. The lower two bits are valid and the upper six bits are reserved in PORT1.DR.
   The lower five bits are valid and the upper three bits are reserved in PORT2.DR.
   The lower four bits are valid and the upper four bits are reserved in PORT3.DR.
   The lower seven bits are valid and the highest order bit is reserved in PORT7.DR.
   The lower three bits are valid and the upper five bits are reserved in PORT8.DR.
   The lower seven bits are valid and the highest order bit is reserved in PORT9.DR.
   The lower six bits are valid and the upper two bits are reserved in PORTA.DR.
   Bit 5 to bit 3, bit 1, and bit 0 are valid and bit 7, bit 6, and bit 2 are reserved in PORTE.DR.
   The lower six bits are valid and the upper two bits are reserved in PORTG.DR.
2. The reserved bits are read as 0. The write value should always be 0.

Bit	Symbol	Bit Name	Description	R/W
b0	B0	Pn0 Output Data Store (n = 1 to 3, 7 to 9, A, B, D, E, G)	Output data are stored.	R/W
b1	B1	Pn1 Output Data Store		R/W
b2	B2	Pn2 Output Data Store		R/W
b3	B3	Pn3 Output Data Store		R/W
b4	B4	Pn4 Output Data Store		R/W
b5	B5	Pn5 Output Data Store		R/W
b6	B6	Pn6 Output Data Store		R/W
b7	B7	Pn7 Output Data Store		R/W

n = 1 to 3, 7 to 9, A, B, D, E, G

Each PORTn.DR (n = 1 to 3, 7 to 9, A, B, D, E, G) stores the output data from the individual pins of the corresponding port used as a general I/O port.

15.1.2.3 Port Register (PORT)

Address: PORT1.PORT 0008 C041h, PORT2.PORT 0008 C042h, PORT3.PORT 0008 C043h, PORT4.PORT 0008 C044h, PORT5.PORT 0008 C045h, PORT6.PORT 0008 C046h, PORT7.PORT 0008 C047h, PORT8.PORT 0008 C048h, PORT9.PORT 0008 C049h, PORTA.PORT 0008 C04Ah, PORTB.PORT 0008 C04Bh, PORTD.PORT 0008 C04Dh, PORTE.PORT 0008 C04Eh, PORTG.PORT 0008 C050h

	b7	b6	b5	b4	b3	b2	b1	b0
	B7	B6	B5	B4	B3	B2	B1	B0
Value after reset:	0	0	0	0	0	0	0	0

Notes:

1. The lower two bits are valid and the upper six bits are reserved in PORT1.PORT.
   The lower five bits are valid and the upper three bits are reserved in PORT2.PORT.
   The lower four bits are valid and the upper four bits are reserved in PORT3.PORT.
   The lower six bits are valid and the upper two bits are reserved in PORT5.PORT.
   The lower six bits are valid and the upper two bits are reserved in PORT6.PORT.
   The lower seven bits are valid and the highest order bit is reserved in PORT7.PORT.
   The lower three bits are valid and the upper five bits are reserved in PORT8.PORT
   The lower seven bits are valid and the highest order bit is reserved in PORT9.PORT.
   The lower six bits are valid and the upper two bits are reserved in PORTA.PORT.
   The lower six bits are valid and the upper two bits are reserved in PORTE.PORT.
   The lower six bits are valid and the upper two bits are reserved in PORTG.PORT.
2. The reserved bits are read as 1. Writing to these bits has no effect.

Bit	Symbol	Bit Name	Description	R/W
b0	B0	Pn0 (n = 1 to 9, A, B, D, E, G)	Individual pin states of the corresponding port are reflected.	R
b1	B1	Pn1		R
b2	B2	Pn2		R
b3	B3	Pn3		R
b4	B4	Pn4		R
b5	B5	Pn5		R
b6	B6	Pn6		R
b7	B7	Pn7		R

n = 1 to 9, A, B, D, E, G

PORT reflects individual pin states of the corresponding port.

When a PORTn.PORT (n = 1 to 9, A, B, D, E, G) is read, the corresponding pin states are read out to here.

15.1.2.4 Input Buffer Control Register (ICR)

Address: PORT1.ICR 0008 C061h, PORT2.ICR 0008 C062h, PORT3.ICR 0008 C063h, PORT4.ICR 0008 C064h, PORT5.ICR 0008 C065h, PORT6.ICR 0008 C066h, PORT7.ICR 0008 C067h, PORT8.ICR 0008 C068h, PORT9.ICR 0008 C069h, PORTA.ICR 0008 C06Ah, PORTB.ICR 0008 C06Bh, PORTD.ICR 0008 C06Dh, PORTE.ICR 0008 C06Eh, PORTG.ICR 0008 C070h

	b7	b6	b5	b4	b3	b2	b1	b0
	B7	B6	B5	B4	B3	B2	B1	B0
Value after reset:	0	0	0	0	0	0	0	0

Notes:

1. The lower two bits are valid and the upper six bits are reserved in PORT1.ICR.
   The lower five bits are valid and the upper three bits are reserved in PORT2.ICR.
   The lower four bits are valid and the upper four bits are reserved in PORT3.ICR.
   The lower six bits are valid and the upper two bits are reserved in PORT5.ICR.
   The lower six bits are valid and the upper two bits are reserved in PORT6.ICR.
   The lower seven bits are valid and the highest order bit is reserved in PORT7.ICR.
   The lower three bits are valid and the upper five bits are reserved in PORT8.ICR.
   The lower seven bits are valid and the highest order bit is reserved in PORT9.ICR.
   The lower six bits are valid and the upper two bits are reserved in PORTA.ICR.
   Bit 5 to bit 3, bit 1, and bit 0 are valid and bit 7, bit 6, and bit 2 are reserved in PORTE.ICR.
   The lower six bits are valid and the upper two bits are reserved in PORTG.ICR.
2. The reserved bits are read as 0. The write value should always be 0.

Bit	Symbol	Bit Name	Description	R/W
b0	B0*1	Pn0 Input Buffer Control (n = 1 to 9, A, B, D, E, G)	0: The input buffer for the corresponding pin is disabled. 1: The input buffer for the corresponding pin is enabled.	R/W
b1	B1*1	Pn1 Input Buffer Control		R/W
b2	B2*1	Pn2 Input Buffer Control		R/W
b3	B3*1	Pn3 Input Buffer Control		R/W
b4	B4*1	Pn4 Input Buffer Control		R/W
b5	B5*1	Pn5 Input Buffer Control		R/W
b6	B6*1	Pn6 Input Buffer Control		R/W
b7	B7*1	Pn7 Input Buffer Control		R/W

n = 1 to 9, A, B, D, E, G

Note 1. For pins being used as input pins for peripheral modules, set the corresponding bits to 1. Set the bits corresponding to pins that are not being used for their input functions or are being used as analog input pins to 0.

Each PORTn.ICR controls the input buffers for the individual pins of the corresponding port.

Each bit of a PORTn.ICR (n=1 to 9, A, B, D, E, G) corresponds to a pin of Pn, and the settings can change from bit to bit. When to be used as an input pin for the peripheral module, the input buffer for the corresponding pin should be enabled beforehand by setting the PORTn.ICR bit to 1. If this register is used as an input pin for the peripheral module while the PORTn.ICR bit is 0, the input signal to the peripheral module is fixed high.

When a Pn.PORT register is read, the pin states of the corresponding port are read out regardless of the values in PORTn.ICR. For bits where the value in PORTn.ICR is 0, however, the value may not reflect the pin state on the corresponding peripheral module side.

Changes in the settings of a PORTn.ICR may generate edges internally, depending on the pin state. For this reason, change the settings of PORTn.ICR while the corresponding input pins are not in use. For example, in the case of IRQi (i = 0 to 7) inputs, change settings of the corresponding PORTn.ICR with interrupts disabled by clearing the IR flag in IRi (i = 64 to 71 ("i" shows an interrupt vector number of the IRQ)) of the interrupt controller (ICU) to 0, and then enable the corresponding interrupts. If a change to a PORTn.ICR setting does generate an edge, negate the edge.

15.1.2.5 Port Function Register 8 (PF8IRQ)

Address: 008 C108h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	ITS1[1:0]		ITS0[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1 to b0	ITS0[1:0]	IRQ0 Pin Select	b1 b0 0 0:P10 is designated as the IRQ0-A input pin. 0 1:PE5 is designated as the IRQ0-B input pin. 1 0:PG0 is designated as the IRQ0-C input pin. 1 1:Setting prohibited	R/W
b3 to b2	ITS1[1:0]	IRQ1 Pin Select	b3 b2 0 0:P11 is designated as the IRQ1-A input pin. 0 1:PE4 is designated as the IRQ1-B input pin. 1 0:PG1 is designated as the IRQ1-C input pin. 1 1:Setting prohibited	R/W
b7 to b4	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

PF8IRQ is used to select pins for IRQ0 and IRQ1 inputs.

ITSi Bit (IRQi Pin Select) (i = 0 and 1)

Each bit selects a pin for an IRQi input.

15.1.2.6 Port Function Register 9 (PF9IRQ)

Address: 008 C109h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	ITS2	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1 to b0	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b2	ITS2	IRQ2 Pin Select	0:PE3 is designated as the IRQ2-A input pin. 1:PG2 is designated as the IRQ2-B input pin.	R/W
b7 to b3	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

PF9IRQ is used to select pins for IRQ2 input.

ITS2 Bit (IRQ2 Pin Select)

This bit selects a pin for an IRQ2 input.

15.1.2.7 Port Function Register A (PFAADC)

Address: 008 C10Ah

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	ADTRG1S	ADTRG0S
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	ADTRG0S	ADTRG0# Input Select	0:PA4 is designated as the ADTRG0#-A input pin. 1:P20 is designated as the ADTRG0#-B input pin.	R/W
b1	ADTRG1S	ADTRG1# Input Select	0:PA5 is designated as the ADTRG1#-A input pin. 1:P21 is designated as the ADTRG1#-B input pin.	R/W
b7 to b2	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

PFAADC is used to select the ADTRG0# and ADTRG1# pins.

ADTRGnS Bit (ADTRGn# Input Select) (n=0 and 1)

This bit selects a pin for an ADTRGn# input.

15.1.2.8 Port Function Register C (PFCMTU)

Address: 008 C10Ch

	b7	b6	b5	b4	b3	b2	b1	b0
	TCLKS[1:0]		—	—	—	—	MTUS1	MTUS0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	MTUS0	MTU3 Pin Select 0	0:PB3 is designated as the MTIOC0A-A pin. 1:P31 is designated as the MTIOC0A-B pin.	R/W
b1	MTUS1	MTU3 Pin Select 1	0:PB2 is designated as the MTIOC0B-A pin. 1:P30 is designated as the MTIOC0B-B pin.	R/W
b5 to b2	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7 to b6	TCLKS[1:0]	MTCLK Pin Select	b7 b6 0 0:P33 is designated as the MTCLKA-A pin. P32 is designated as the MTCLKB-A pin. P31 is designated as the MTCLKC-A pin. P30 is designated as the MTCLKD-A pin. 0 1:P21 is designated as the MTCLKA-B pin. P20 is designated as the MTCLKB-B pin. P11 is designated as the MTCLKC-B pin. P10 is designated as the MTCLKD-B pin. 1 0:PE4 is designated as the MTCLKC-C pin. PE3 is designated as the MTCLKD-C pin. (MTCLKA pin and MTCLKB pins cannot be selected.) 1 1:Setting prohibited	R/W

PFCMTU is used to select pins for MTU3.

MTUSi Bit (MTU3 Pin Select) (i = 0 and 1)

Each bit selects a pin for an MTU3 input/output.

TCLKS[1:0] Bit (MTCLK Pin Select)

This bit selects a pin for a MTCLK input of the MTU3.

15.1.2.9 Port Function Register D (PFDGPT)

Address: 0008 C10Dh

	b7	b6	b5	b4	b3	b2	b1	b0
			—	—	—	—	—	GPTS
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	GPTS	GPT Pin Select	0:P71 is designated as the GTIOC0A-A pin. P74 is designated as the GTIOC0B-A pin. P72 is designated as the GTIOC1A-A pin. P75 is designated as the GTIOC1B -A pin. P73 is designated as the GTIOC2A-A pin. P76 is designated as the GTIOC2B-A pin. 1:PD7 is designated as the GTIOC0A-B pin. PD6 is designated as the GTIOC0B-B pin. PD5 is designated as the GTIOC1A-B pin. PD4 is designated as the GTIOC1B-B pin. PD3 is designated as the GTIOC2A-B pin. PD2 is designated as the GTIOC2B-B pin.	R/W
b7 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

PFDGPT is used to select a pin for GPT.

GPTS Bit (GPTI/O Pin Select)

Each bit selects a pin for a GPT input/output.

15.1.2.10 Port Function Register F (PFFSCI)

Address: 0008 C10Fh

	b7	b6	b5	b4	b3	b2	b1	b0
			—	—	—	SCI2S	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1 to b0	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b2	SCI2S	SCI2 I/O Select	0:PB6 is designated as the RXD2-A pin. PB7 is designated as the SCK2-A pin. PB5 is designated as the TXD2-A pin. 1:P80 is designated as the RXD2-B pin. P82 is designated as the SCK2-B pin. P81 is designated as the TXD2-B pin.	R/W
b7 to b3	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

PFFSCI is used to select pins for SCI.

SCI2S Bit (SCI2 I/O Pin Select)

Each bit selects a pin for an SCI channel-2 input/output.

15.1.2.11 Port Function Register G (PFGSPI)

Address: 0008 C110h

	b7	b6	b5	b4	b3	b2	b1	b0
	SSL3E	SSL2E	SSL1E	SSL0E	MISOE	MOSIE	RSPCKE	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b1	RSPCKE	RSPCK Output Enable	0:RSPCK pin is disabled. 1:RSPCK pin is enabled.	R/W
b2	MOSIE	MOSI Output Enable	0:MOSI pin is disabled. 1:MOSI pin is enabled.	R/W
b3	MISOE	MISO Output Enable	0:MISO pin is disabled. 1:MISO pin is enabled.	R/W
b4	SSL0E	SSL0 Output Enable	0:SSL0 pin is disabled. 1:SSL0 pin is enabled.	R/W
b5	SSL1E	SSL1 Output Enable	0:SSL1 pin is disabled. 1:SSL1 pin is enabled.	R/W
b6	SSL2E	SSL2 Output Enable	0:SSL2 pin is disabled. 1:SSL2 pin is enabled.	R/W
b7	SSL3E	SSL3 Output Enable	0:SSL3 pin is disabled. 1:SSL3 pin is enabled.	R/W

PFGSPI is used to select I/O pins for RSPI.

RSPCKE Bit (RSPCK Output Enable)

This bit enables or disables the output of the RSPCK pin. Set this bit to 1 to use the RSPCK pin.

MOSIE Bit (MOSI Output Enable)

This bit enables or disables the output of the MOSI pin. Set this bit to 1 to use the MOSI pin.

MISOE Bit (MISO Output Enable)

This bit enables or disables the output of the MISO pin. Set this bit to 1 to use the MISO pin.

SSL0E Bit (SSL0 Output Enable)

This bit enables or disables the output of the SSL0 pin. Set this bit to 1 to use the SSL0 pin.

SSL1E Bit (SSL1 Output Enable)

This bit enables or disables the output of the SSL1 pin. Set this bit to 1 to use the SSL1 pin.

SSL2E Bit (SSL2 Output Enable)

This bit enables or disables the output of the SSL2 pin. Set this bit to 1 to use the SSL2 pin.

SSL3E Bit (SSL3 Output Enable)

This bit enables or disables the output of the SSL3 pin. Set this bit to 1 to use the SSL3 pin.

15.1.2.12 Port Function Register H (PFHSPI)

Address: 0008 C111h

	b7	b6	b5	b4	b3	b2	b1	b0
			—	—	—	—	RSPIS[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1 to b0	RSPIS[1:0]	RSPI Pin Select	b1 b0 0 0:P22 is designated as the MISO-A pin. P23 is designated as the MOSI-A pin. P24 is designated as the RSPCK-A pin. P30 is designated as the SSL0-A pin. P31 is designated as the SSL1-A pin. P32 is designated as the SSL2-A pin. P33 is designated as the SSL3-A pin. 0 1:PA5 is designated as the MISO-B pin. PB0 is designated as the MOSI-B pin. PA4 is designated as the RSPCK-B pin. PA3 is designated as the SSL0-B pin. PA2 is designated as the SSL1-B pin. PA1 is designated as the SSL2-B pin. PA0 is designated as the SSL3-B pin. 1 0:PD1 is designated as the MISO-C pin. PD2 is designated as the MOSI-C pin. PD0 is designated as the RSPCK-C pin. PD6 is designated as the SSL0-C pin. PD7 is designated as the SSL1-C pin. PE0 is designated as the SSL2-C pin. PE1 is designated as the SSL3-C pin. 1 1:Setting prohibited	R/W
b7 to b2	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

PFHSPI is used to select I/O pins for RSPI channel.

RSPIS[1:0] Bit (RSPI Pin Select)

This bit selects a pin for an RSPI input/output.

As an enable bit is provided for each RSPI input/output pin, the input/output pin is selectable while the corresponding enable bit is 1. Otherwise, the pin cannot be selected.

15.1.2.13 Port Function Register J (PFJCAN)

Address: 0008 C113h

	b7	b6	b5	b4	b3	b2	b1	b0
	CANS[1:0]		—	—	—	—	—	CANE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	CANE	CAN Pin Enable	0: The CTX and CRX pins are disabled. 1: The CTX and CRX pins are enabled.	R/W
b5 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7 to b6	CANS[1:0]	CAN Pin Select	b7 b6 0 0: PB5 is designated as the CTX-A pin. PB6 is designated as the CRX-A pin. 0 1: P23 is designated as the CTX-B pin. P22 is designated as the CRX-B pin. 1 0: PE0 is designated as the CRX-C pin. PD7 is designated as the CTX-C pin. 1 1: Setting prohibited	R/W

PFJCAN is used to select I/O pins for the CAN.

CANE Bit (CAN Pin Enable)

This bit enables or disables the CAN pin. Set this bit to 1 to use the CAN pin.

CANS[1:0] Bit (CAN Pin Select)

These bits select I/O pins for the CAN.

15.1.2.14 Port Function Register K (PFKLIN)

Address: 0008 C114h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	LINE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	LINE	LIN Pin Enable	0: LTX and LRX pins are disabled. 1: LTX and LRX pins are enabled.	R/W
b7 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

PFKLIN is used to set I/O pins for the LIN.

LINE Bit (LIN Pin Enable)

This bit enables or disables the LIN pin. Set this bit to 1 to use the LIN pin.

15.1.2.15 Port Function Register M (PFMPOE)

Address: 0008 C116h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	POE11E	POE10E	POE8E	POE4E	POE0E
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	POE0E	POE0# Input Enable	0:Designated as an I/O port pin 1:Designated as the POEn# input pin (n = 0, 4, 8, 10, 11)	R/W*1
b1	POE4E	POE4# Input Enable		R/W*1
b2	POE8E	POE8# Input Enable		R/W*1
b3	POE10E	POE10# Input Enable		R/W*1
b4	POE11E	POE11# Input Enable		R/W*
b7 to b5	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W*1

Note 1. The first round of writing after a reset is enabled; though subsequent writing is not allowed.

PFMPOE enables or disables POEn# input pins.
To prevent the error in the system, be sure to write to this register after a reset.
The first round of writing after a reset is only enabled.

POEnE Bit (POEn# Input Enable) (n = 0, 4, 8, 10, 11)

Each bit enables or disables the corresponding POEn# input.
To use POEn#, set the corresponding POEnE bit to 1.

15.1.2.16 Port Function Register N (PFNPOE)

Address: 0008 C117h

	b7	b6	b5	b4	b3	b2	b1	b0
	POE10S	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b6 to b0	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W*1
b7	POE10S	POE10# Input Select	0:PE2 is designated as the POE10#-A input pin. 1:PE4 B is designated as the POE10# input pin.	R/W

Note 1. The first round of writing after a reset is enabled; though subsequent writing is not allowed.

PFNPOE enables or disables POEn# input pins.
To prevent the error in the system, be sure to write to this register after a reset.
The first round of writing after a reset is only enabled.

POE10S Bit (POE10# Input Select)

This bit select input pins for the POE10#.

15.1.3 Settings of Ports

When individual pins for peripheral modules are enabled, the settings for each port are modified.
An input pin for the peripheral module is specified independently by the peripheral module. To use an input pin for the peripheral module, the corresponding bit in the input buffer control register (PORTn.ICR) should be set to 1 to enable the input buffer, except for the port register read, NMI, and POEn# pin inputs.
The pins that function as output pins and I/O pins should be enabled for respective peripheral modules. If a conflict occurs among the output signal enable settings for peripheral modules, that are multiplexed to the same port, the priority will be handled according to the port-multiplexed priority.
Table 15.15 lists the port-multiplexed priority for peripheral modules.

Table 15.5 Port-Multiplexed Priority for Peripheral Modules (112-Pin LQFP)

Priority		Module Name	Output Pins
High	1	RSPI	RSPCK, MOSI, MISO, SSL0 to SSL3
↑	2	CAN	CTX
	3	LIN	LTX
	4	MTU0 to MTU7	MTIOC0A, MTIOC0B, MTIOC0C, MTIOC0D, MTIOC1A, MTIOC1B, MTIOC2A, MTIOC2B, MTIOC3A, MTIOC3B, MTIOC3C, MTIOC3D, MTIOC4A, MTIOC4B, MTIOC4C, MTIOC4D, MTIOC6A, MTIOC6B, MTIOC6C, MTIOC6D, MTIOC7A, MTIOC7B, MTIOC7C, MTIOC7D
	5	GPT0 to GPT3	GTIOC0A, GTIOC0B, GTIOC1A, GTIOC1B, GTIOC2A, GTIOC2B, GTIOC3A, GTIOC3B
	6	SCI0 to SCI2	SCK0 to SCK2, TXD0 to TXD2
	7	RIIC	SCL, SDA
	8	IOPORT	P10 to P11, P20 to P24, P30 to P33, P70 to P76, P80 to P82, P90 to P96, PA0 to PA5, PB0 to PB7, PD0 to PD7, PE0 to PE1, PE3 to PE5, PG0 to PG5
Low			

15.1.4 List of Output Enable Settings

Table 15.6 lists the output enable settings for each port.
For details on the applicable output signals, see descriptions of the registers for each peripheral module.
Setting the port function register changes the functions of peripheral-module pins with names ending in A to C.

Table 15.6 Output Enable Settings for Each Port (112-pin LQFP) (1 / 5)

Port	Module Name	Output Signal Name	Port Function Register Settings	Peripheral Module Settings
P10	PORT1	P10		PORT1.DDR.B0 = 1
P11	PORT1	P11		PORT1.DDR.B1 = 1
P20	PORT2	P20		PORT2.DDR.B0 = 1
P21	PORT2	P21		PORT2.DDR.B1 = 1
P22	RSPI	MISO-A	PFGSPI.MISOE = 1 PFHSPI.RSPIS[1:0] = 00	(In addition to the pin enable setting, input/ output switching function for the peripheral module is provided.)
	PORT2	P22		PORT2.DDR.B2 = 1
P23	RSPI	MOSI-A	PFGSPI.MOSIE = 1 PFHSPI.RSPIS[1:0] = 00	(In addition to the pin enable setting, input/ output switching function for the peripheral module is provided.)
	CAN	CTX-B	PFJCAN.CANE =1 PFJCAN.CANS[1:0] = 01	(The signal output state is specified by the peripheral module settings.)
	LIN	LTX	PFKLIN.LINE = 1	(The signal output state is specified by the peripheral module settings.)
	PORT2	P23		PORT2.DDR.B3 =1
P24	RSPI	RSPCK-A	PFGSPI.RSPCKE =1 PFHSPI.RSPIS[1:0] = 00	(In addition to the pin enable setting, input/ output switching function for the peripheral module is provided.)
	PORT2	P24		PORT2.DDR.B4 = 1
P30	RSPI	SSL0-A	PFGSPI.SSL0E = 1 PFHSPI.RSPIS[1:0] = 00	(In addition to the pin enable setting, input/ output switching function for the peripheral module is provided.)
	MTU0	MTIOC0B-B	PFCMTU.MTUS1 = 1	(The signal output state is specified by the peripheral module settings.)
	PORT3	P30		PORT3.DDR.B0 = 1
P31	RSPI	SSL1-A	PFGSPI.SSL1E = 1 PFHSPI.RSPIS[1:0] = 00	(The signal output state is specified by the peripheral module settings.)
	MTU0	MTIOC0A-B	PFCMTU.MTUS0 = 1	(The signal output state is specified by the peripheral module settings.)
	PORT3	P31		PORT3.DDR.B1 = 1
P32	RSPI	SSL2-A	PFGSPI.SSL2E = 1 PFHSPI.RSPIS[1:0] = 00	(The signal output state is specified by the peripheral module settings.)
	MTU3	MTIOC3C		(The signal output state is specified by the peripheral module settings.)
	PORT3	P32		PORT3.DDR.B2 = 1
P33	RSPI	SSL3-A	PFGSPI.SSL3E = 1 PFHSPI.RSPIS[1:0] = 00	(The signal output state is specified by the peripheral module settings.)
	MTU3	MTIOC3A		(The signal output state is specified by the peripheral module settings.)
	PORT3	P33		PORT3.DDR.B3 = 1
P70	PORT7	P70		PORT7.DDR.B0 = 1

Table 15.6 Output Enable Settings for Each Port (112-pin LQFP) (2 / 5)

Port	Module Name	Output Signal Name	Port Function Register Settings	Peripheral Module Settings
P71	MTU3	MTIOC3B		(The signal output state is specified by the peripheral module settings.)
	GPT0	GTIOC0A-A	PFDGPT.GPTS = 0	(The signal output state is specified by the peripheral module settings.)
	PORT7	P71		PORT7.DDR.B1 = 1
P72	MTU4	MTIOC4A		(The signal output state is specified by the peripheral module settings.)
	GPT1	GTIOC1A-A	PFDGPT.GPTS = 0	(The signal output state is specified by the peripheral module settings.)
	PORT7	P72		PORT7.DDR.B2 = 1
P73	MTU4	MTIOC4B		(The signal output state is specified by the peripheral module settings.)
	GPT2	GTIOC2A-A	PFDGPT.GPTS = 0	(The signal output state is specified by the peripheral module settings.)
	PORT7	P73		PORT7.DDR.B3 = 1
P74	MTU3	MTIOC3D		(The signal output state is specified by the peripheral module settings.)
	GPT0	GTIOC0B-A	PFDGPT.GPTS = 0	(The signal output state is specified by the peripheral module settings.)
	PORT7	P74		PORT7.DDR.B4 = 1
P75	MTU4	MTIOC4C		(The signal output state is specified by the peripheral module settings.)
	GPT1	GTIOC1B-A	PFDGPT.GPTS = 0	(The signal output state is specified by the peripheral module settings.)
	PORT7	P75		PORT7.DDR.B5 = 1
P76	MTU4	MTIOC4D		(The signal output state is specified by the peripheral module settings.)
	GPT2	GTIOC2B-A	PFDGPT.GPTS = 0	(The signal output state is specified by the peripheral module settings.)
	PORT7	P76		PORT7.DDR.B6 = 1
P80	PORT8	P80		PORT8.DDR.B0 = 1
P81	SCI2	TXD2-B	PFFSCI.SCI2S = 1	SCI2.SCR.TE = 1
	PORT8	P81		PORT8.DDR.B1 = 1
P82	SCI2	SCK2-B	PFFSCI.SCI2S = 1	When SCI2.SCMR.SMIF = 1: While SMR.GM = 0, SCR.CKE[1:0] = 01 or SMR.GM = 1, SCR.TE = 1 or SCR.RE = 1 When SCI2.SCMR.SMIF = 0: While SMR.CM = 0, SCR.CKE[1:0] = 01 or SMR.CM = 1, SCR.CKE[1] = 0, SCR.TE =1 or SCR.RE=1
	PORT8	P82		PORT8.DDR.B2 = 1
P90	MTU7	MTIOC7D		(The signal output state is specified by the peripheral module settings.)
	I/O port	P90		PORT9.DDR.B0 = 1
P91	MTU7	MTIOC7C		(The signal output state is specified by the peripheral module settings.)
	PORT9	P91		PORT9.DDR.B1 = 1
P92	MTU6	MTIOC6D		(The signal output state is specified by the peripheral module settings.)
	PORT9	P92		PORT9.DDR.B2 = 1

Table 15.6 Output Enable Settings for Each Port (112-pin LQFP) (3 / 5)

Port	Module Name	Output Signal Name	Port Function Register Settings	Peripheral Module Settings
P93	MTU7	MTIOC7B		(The signal output state is specified by the peripheral module settings.)
	PORT9	P93		PORT9.DDR.B3 = 1
P94	MTU7	MTIOC7A		(The signal output state is specified by the peripheral module settings.)
	PORT9	P94		PORT9.DDR.B4 = 1
P95	MTU6	MTIOC6B		The signal output state is specified by the peripheral module settings.)
	PORT9	P95		PORT9.DDR.B5 = 1
P96	PORT9	P96		PORT9.DDR.B6 = 1
PA0	RSPI	SSL3-B	PFGSPI.SSL3E = 1 PFHSPI.RSPIS[1:0] = 01	(The signal output state is specified by the peripheral module settings.)
	MTU6	MTIOC6C		(The signal output state is specified by the peripheral module settings.)
	PORTA	PA0		PORTA.DDR.B0 = 1
PA1	RSPI	SSL2-B	PFGSPI.SSL2E = 1 PFHSPI.RSPIS[1:0] = 01	(The signal output state is specified by the peripheral module settings.)
	MTU6	MTIOC6A		(The signal output state is specified by the peripheral module settings.)
	PORTA	PA1		PORTA.DDR.B1 = 1
PA2	RSPI	SSL1-B	PFGSPI.SSL1E = 1 PFHSPI.RSPIS[1:0] = 01	(The signal output state is specified by the peripheral module settings.)
	MTU2	MTIOC2B		(The signal output state is specified by the peripheral module settings.)
	PORTA	PA2		PORTA.DDR.B2 = 1
PA3	RSPI	SSL0-B	PFGSPI.SSL0E = 1 PFHSPI.RSPIS[1:0] = 01	(In addition to the pin enable setting, input/ output switching function for the peripheral module is provided.)
	MTU2	MTIOC2A		(The signal output state is specified by the peripheral module settings.)
	PORTA	PA3		PORTA.DDR.B3 = 1
PA4	RSPI	RSPCK-B	PFGSPI.RSPCKE = 1 PFHSPI.RSPIS[1:0] = 01	(In addition to the pin enable setting, input/ output switching function for the peripheral module is provided.)
	MTU1	MTIOC1B		(The signal output state is specified by the peripheral module settings.)
	PORTA	PA4		PORTA.DDR.B4 = 1
PA5	RSPI	MISO-B	PFGSPI.MISOE = 1 PFHSPI.RSPIS[1:0] = 01	(In addition to the pin enable setting, input/ output switching function for the peripheral module is provided.)
	MTU1	MTIOC1A		(The signal output state is specified by the peripheral module settings.)
	PORTA	PA5		PORTA.DDR.B5 = 1
PB0	RSPI	MOSI-B	PFGSPI.MOSIE = 1 PFHSPI.RSPIS[1:0] = 01	(In addition to the pin enable setting, input/ output switching function for the peripheral module is provided.))
	MTU0	MTIOC0D		(The signal output state is specified by the peripheral module settings.)
	PORTB	PB0		PORTB.DDR.B0 = 1

Table 15.6 Output Enable Settings for Each Port (112-pin LQFP) (4 / 5)

Port	Module Name	Output Signal Name	Port Function Register Settings	Peripheral Module Settings
PB1	MTU0	MTIOC0C		(The signal output state is specified by the peripheral module settings.)
	RIIC	SCL		RIIC.ICCR1.ICE = 1
	PORTB	PB1		PORTB.DDR.B1 = 1
PB2	MTU0	MTIOC0B-A	PFCMTU.MTUS1 = 0	(The signal output state is specified by the peripheral module settings.)
	SCI0	TXD0		SCI0.SCR.TE = 1
	RIIC	SDA		RIIC.ICCR1.ICE = 1
	PORTB	PB2		PORTB.DDR.B2 = 1
PB3	MTU0	MTIOC0A-A	PFCMTU.MTUS0 = 0	(The signal output state is specified by the peripheral module settings.)
	SCI0	SCK0		When SCI0.SCMR.SMIF = 1: While SMR.GM = 0, SCR.CKE[1:0] = 01 or SMR.GM = 1, SCR.TE = 1 or SCR.RE = 1 When SCI0.SCMR.SMIF = 0: While SMR.CM = 0, SCR.CKE[1:0] = 01 or SMR.CM = 1, SCR.CKE[1] = 0, SCR.TE = 1 or SCR.RE = 1
	PORTB	PB3		PORTB.DDR.B3 = 1
PB4	PORTB	PB4		PORTB.DDR.B4 = 1
PB5	CAN	CTX-A	PFJCAN.CANE = 1 PFJCAN.CANS[1:0] = 00	(The signal output state is specified by the peripheral module settings.)
	SCI2	TXD2-A	PFFSCI.SCI2S = 0	SCI2.SCR.TE = 1
	PORTB	PB5		PORTB.DDR.B5 = 1
PB6	PORTB	PB6		PORTB.DDR.B6 = 1
PB7	SCI2	SCK2-A	PFFSCI.SCI2S = 0	When SCI2.SCMR.SMIF =1: While SMR.GM = 0, SCR.CKE[1:0] = 01 or SMR.GM = 1, SCR.TE = 1 or SCR.RE = 1 When SCI2.SCMR.SMIF = 0 While SMR.CM = 0, SCR.CKE[1:0] = 01 or SMR.CM = 1, SCR.CKE[1] = 0, SCR.TE = 1 or SCR.RE = 1
	PORTB	PB7		PORTB.DDR.B7 = 1
PD0	RSPI	RSPCK-C	PFGSPI.RSPCKE = 1 PFHSPI.RSPIS[1:0] = 10	(In addition to the pin enable setting, input/ output switching function for the peripheral module is provided.))
	GPT3	GTIOC3B		(The signal output state is specified by the peripheral module settings.)
	PORTD	PD0		PORTD.DDR.B0 = 1
PD1	RSPI	MISO-C	PFGSPI.MISOE = 1 PFHSPI.RSPIS[1:0] = 10	(In addition to the pin enable setting, input/ output switching function for the peripheral module is provided.))
	GPT3	GTIOC3A		(The signal output state is specified by the peripheral module settings.)
	PORTD	PD1		PORTD.DDR.B1 = 1
PD2	RSPI	MOSI-C	PFGSPI.MISOE = 1 PFHSPI.RSPIS[1:0] = 10	(In addition to the pin enable setting, input/ output switching function for the peripheral module is provided.))
	GPT2	GTIOC2B-B	PFDGPT.GPTS = 1	(The signal output state is specified by the peripheral module settings.)
	PORTD	PD2		PORTD.DDR.B2 = 1

Table 15.6 Output Enable Settings for Each Port (112-pin LQFP) (5 / 5)

Port	Module Name	Output Signal Name	Port Function Register Settings	Peripheral Module Settings
PD3	GPT2	GTIOC2A-B	PFDGPT.GPTS = 1	(The signal output state is specified by the peripheral module settings.)
	SCI1	TXD1		SCI1.SCR.TE = 1
	PORTD	PD3		PORTD.DDR.B3 = 1
PD4	GPT1	GTIOC1B-B	PFDGPT.GPTS = 1	(The signal output state is specified by the peripheral module settings.)
	SCI1	SCK1		When SCI1.SCMR.SMIF = 1: While SMR.GM = 0, SCR.CKE[1:0] = 01 or SMR.GM = 1, SCR.TE = 1 or SCR.RE = 1 When SCI1.SCMR.SMIF = 0: While SMR.CM = 0, SCR.CKE[1:0] = 01 or SMR.CM = 1, SCR.CKE[1] = 0, SCR.TE = 1 or SCR.RE = 1
	PORTD	PD4		PORTD.DDR.B4 = 1
PD5	GPT1	GTIOC1A-B	PFDGPT.GPTS = 1	(The signal output state is specified by the peripheral module settings.)
	PORTD	PD5		PORTD.DDR.B5 = 1
PD6	RSPI	SSL0-C	PFGSPI.SSL0E = 1 PFHSPI.RSPIS[1:0] = 10	(In addition to the pin enable setting, input/output switching function for the peripheral module is provided.)
	GPT0	GTIOC0B-B	PFDGPT.GPTS = 1	(The signal output state is specified by the peripheral module settings.)
	PORTD	PD6		PORTD.DDR.B6 = 1
PD7	RSPI	SSL1-C	PFGSPI.SSL1E = 1 PFHSPI.RSPIS[1:0] = 10	(The signal output state is specified by the peripheral module settings.)
	CAN	CTX-C	PFJCAN.CANE = 1 PFJCAN.CANS[1:0] = 10	(The signal output state is specified by the peripheral module settings.)
	GPT0	GTIOC0A-B	PFDGPT.GPTS = 1	(The signal output state is specified by the peripheral module settings.)
	PORTD	PD7		PORTD.DDR.B7 = 1
PE0	RSPI	SSL2-C	PFGSPI.SSL2E = 1 PFHSPI.RSPIS[1:0] = 10	(The signal output state is specified by the peripheral module settings.)
	PORTE	PE0		PORTE.DDR.B0 = 1
PE1	RSPI	SSL3-C	PFGSPI.SSL3E = 1 PFHSPI.RSPIS[1:0] = 10	(The signal output state is specified by the peripheral module settings.)
	PORTE	PE1		PORTE.DDR.B1 = 1
PE3	PORTE	PE3		PORTE.DDR.B3 = 1
PE4	PORTE	PE4		PORTE.DDR.B4 = 1
PE5	PORTE	PE5		PORTE.DDR.B5 = 1
PG0	PORTG	PG0		PORTG.DDR.B0 = 1
PG1	PORTG	PG1		PORTG.DDR.B1 = 1
PG2	PORTG	PG2		PORTG.DDR.B2 = 1
PG3	PORTG	PG3		PORTG.DDR.B3 = 1
PG4	PORTG	PG4		PORTG.DDR.B4 = 1
PG5	PORTG	PG5		PORTG.DDR.B5 = 1

15.1.5 Treatment of Unused Pins

The treatment of unused pins is listed in Table 15.7.

Table 15.7 Treatment of Unused Pin (112-pin LQFP)

Pin Name	Treatment
EMLE	Connect this pin to Vss via a pull-down resistor.
MD1, MD0	(Always used as mode pins)
MDE	(Always used as mode pins)
RES#	Connect this pin to Vcc via a pull-up resistor.
PE2/NMI/POE10#-A	Connect this pin to Vcc via a pull-up resistor.
EXTAL	(Always used as a clock pin)
XTAL	Leave these pins open.
WDTOVF#	Leave these pins open.
Port 3, 7 to 9, A, B, D, E, G	Connect these pins to Vcc via a pull-up resistor or to Vss via a pull-down resistor These pins can be left while PORTn.ICR is in the initial state (the input buffer disabled)*1.
Port 4	Connect these pins to AVCCO via a pull-up resistor or to AVSSO via a pull-down resistor These pins can be left while PORTn.ICR is in the initial state (the input buffer disabled)*1.
Port 5 to 6	Connect these pins to AVCC via a pull-up resistor or to AVSS via a pull-down resistor These pins can be left while PORTn.ICR is in the initial state (the input buffer disabled)*1.
VREFH0	Connect this pin to AVCC0
VREFL0	Connect this pin to AVSS0
VREF	Connect this pin to AVCC
TRST#, TMS, TCK, TDI	Connect these pins to Vcc via a pull-up resistor or to Vss via a pull-down resistor
TDO	Leave these pins open.

Note 1. Do not change the initial value of PORTn.ICR. Changing the initial value may generate shoot-through current.

15.2 I/O Port [for 100-Pin LQFP]

The RX62T Group (100-Pin LQFP) has 13 I/O ports (ports 1 to 9 and A, B, D, E), which handle 55 I/O pins.

15.2.1 Overview

Table 15.8 gives the specifications of the I/O ports and Table 15.9 lists I/O ports and pin functions.

Table 15.8 Specifications of I/O Ports (100-Pin LQFP)

Item	Description
I/O pins	55
Input pins	21
Number of ports	13 (1 to 9, A, B, D, E)
Open drain outputs	2 (RIIC pin)
Large-current output	12 (MTU3 pin and GPT pin)
Schmitt trigger input pins	All port inputs, CAN inputs, IRQ inputs, MTU3 inputs, POE3 inputs, RIIC inputs, SCI inputs, A/D trigger inputs, NMI inputs, GPT inputs, and LIN inputs
Others	Each pin is capable of driving a capacitive load of 30 pF in the case of a TTL load. When configured as an output, a pin is capable of driving a Darlington transistor. A pin is always capable of reading the status of the pins.

Table 15.9 Port Functions (100-Pin LQFP) (1 / 3)

			Function						
Port	Description	Bit	I/O	Input	Output	CMOS Input	Schmitt Trigger Input	Open Drain Output Capability	Large-Current Output
Port 1	General I/O port pins, MTU3 inputs, and interrupt inputs	0	P10	MTCLKD-B/ IRQ0-A		—	All input functions	—	—
		1	P11	MTCLKC-B/ IRQ1-A			All input functions		
Port 2	General I/O port pins, MTU3 inputs, interrupt inputs, A/D converter inputs, RSPI I/O signal, LIN I/O signal, and CAN I/O signal	0	P20	MTCLKB-B/ IRQ7/ ADTRG0#-B		—	All input functions	—	—
		1	P21	MTCLKA-B/ IRQ6/ ADTRG1#-B			All input functions		
		2	P22/MISO-A	LRX/CRX-B/ ADTRG#		MISO-A	P22/LRX/CRX-B/ ADTRG#		
		3	P23/MOSI-A		LTX/CTX-B	MOSI-A	P23		
		4	P24/RSPCK-A			RSPCK-A	P24		
Port 3	General I/O port pins, MTU3 I/O signal, and RSPI I/O signal	0	P30/MTIOC0B-B/ SSL0-A	MTCLKD-A		SSL0-A	P30/MTIOC0B-B/ MTCLKD-A	—	—
		1	P31/MTIOC0A-B	MTCLKC-A	SSL1-A	—	All input functions		
		2	P32/MTIOC3C	MTCLKB-A	SSL2-A		All input functions		
		3	P33/MTIOC3A	MTCLKA-A	SSL3-A		All input functions		
Port 4	A/D converter inputs and general input port pins	0		P40/AN000		—	P40	—	—
		1		P41/AN001			P41		
		2		P42/AN002			P42		
		3		P43/AN003/ CVREFL			P43		
		4		P44/AN100			P44		
		5		P45/AN101			P45		
		6		P46/AN102			P46		
		7		P47/AN103/ CVREFH			P47		

Table 15.9 Port Functions (100-Pin LQFP) (2 / 3)

Port	Description	Bit	Function			CMOS Input	Schmitt Trigger Input	Open Drain Output Capability	Large-Current Output
			I/O	Input	Output				
Port 5	A/D converter inputs and general input port pins	0		P50/AN6		—	P50	—	—
		1		P51/AN7			P51		
		2		P52/AN8			P52		
		3		P53/AN9			P53		
		4		P54/AN10			P54		
		5		P55/AN11			P55		
Port 6	A/D converter inputs and general input port pins	0		P60/AN0		—	P60	—	—
		1		P61/AN1			P61		
		2		P62/AN2			P62		
		3		P63/AN3			P63		
		4		P64/AN4			P64		
		5		P65/AN5			P65		
Port 7	General I/O port pins, POE3 inputs, interrupt inputs, MTU3 I/O signal, and GPT I/O signal	0	P70	POE0#/IRQ5		—	All input functions	—	—
		1	P71/MTIOC3B/ GTIOC0A-A				All input functions		√
		2	P72/MTIOC4A/ GTIOC1A-A				All input functions		√
		3	P73/MTIOC4B/ GTIOC2A-A				All input functions		√
		4	P74/MTIOC3D/ GTIOC0B-A				All input functions		√
		5	P75/MTIOC4C/ GTIOC1B-A				All input functions		√
		6	P76/MTIOC4D/ GTIOC2B-A				All input functions		√
Port 8	General I/O port pins, SCI I/O signal, and MTU3 inputs	0	P80	RXD2-B/ MTIC5W		—	All input functions	—	—
		1	P81	MTIC5V	TXD2-B		All input functions		
		2	P82/SCK2-B	MTIC5U			All input functions		
Port 9	General I/O port pins, MTU3 I/O signal, POE3 inputs, and interrupt inputs	0	P90/MTIOC7D			—	All input functions	—	√
		1	P91/MTIOC7C				All input functions		√
		2	P92/MTIOC6D				All input functions		√
		3	P93/MTIOC7B				All input functions		√
		4	P94/MTIOC7A				All input functions		√
		5	P95/MTIOC6B				All input functions		√
		6	P96	POE4#/IRQ4			All input functions		—
Port A	General I/O port pins, MTU3 I/O signal, RSPI I/O signal, and A/D converter inputs	0	PA0/MTIOC6C		SSL3-B	—	All input functions	—	—
		1	PA1/MTIOC6A		SSL2-B		All input functions		
		2	PA2/MTIOC2B		SSL1-B		All input functions		
		3	PA3/MTIOC2A/ SSL0-B			SSL0-B	PA3/MTIOC2A		
		4	PA4/MTIOC1B/ RSPCK-B	ADTRG0#-A		RSPCK-B	PA4/MTIOC1B/ ADTRG0#-A		
		5	PA5/MTIOC1A/ MISO-B	ADTRG1#-A		MISO-B	PA5/MTIOC1A/ ADTRG1#-A		

Table 15.9 Port Functions (100-Pin LQFP) (3 / 3)

Port	Description	Bit	Function			CMOS Input	Schmitt Trigger Input	Open Drain Output Capability	Large-Current Output
			I/O	Input	Output				
Port B	General I/O port pins, MTU3 I/O signal, RSPI I/O signal, RIIC I/O signal, SCI I/O signal, GPT inputs, POE3 inputs, interrupt inputs, CAN I/O signal, and trace outputs	0	PB0/MTIOC0D/ MOSI-B			MOSI-B	PB0/MTIOC0D	—	—
		1	PB1/MTIOC0C/ SCL	RXD0		—	All input functions	? (SCL only)	—
		2	PB2/MTIOC0B-A/ SDA		TXD0		All input functions	? (SDA only)	—
		3	PB3/MTIOC0A-A/ SCK0				All input functions	—	—
		4	PB4	GTETRG/ POE8#/IRQ3			All input functions		
		5	PB5		TXD2-A/ CTX-A/ TRSYNC		All input functions		
		6	PB6	RXD2-A/CRX-A	TRDATA0		All input functions		
		7	PB7/SCK2-A		TRDATA1		All input functions		
Port D	General I/O port pins, GPT I/O signal, RSPI I/O signal, SCI I/O signal, CAN outputs, trace outputs, and On-chip emulator I/O signal	0	PD0/GTIOC3B/ RSPCK-C		TRDATA2	RSPCK-C	PD0/GTIOC3B	—	—
		1	PD1/GTIOC3A/ MISO-C		TRDATA3	MISO-C	PD1/GTIOC3A		
		2	PD2/GTIOC2B-B/ MOSI-C		TRCLK	MOSI-C	PD2/GTIOC2B-B		
		3	PD3/GTIOC2A-B		TXD1/TDO	—	All input functions		
		4	PD4/GTIOC1B-B/ SCK1	TCK		—	All input functions		
		5	PD5/GTIOC1A-B	RXD1/TDI		—	All input functions		
		6	PD6/GTIOC0B-B/ SSL0-C	TMS		SSL0-C	PD6/GTIOC0B-B		
		7	PD7/GTIOC0A-B	TRST#	SSL1-C/ CTX-C	—	All input functions		
Port E	General I/O port pins, CAN inputs, RSPI outputs, POE3 inputs, MTU3 inputs, and interrupt inputs	0	PE0	CRX-C	SSL2-C	—	All input functions	—	—
		1	PE1		SSL3-C		All input functions		
		2		PE2/POE10#-A/NMI			All input functions		
		3	PE3	MTCLKD-C/ POE11#/ IRQ2-A			All input functions		
		4	PE4	MTCLKC-C/ POE10#-B/ IRQ1-B			All input functions		
		5	PE5	IRQ0-B			All input functions		

15.2.2 Register Descriptions

Table 15.10 lists registers of I/O ports, and Table 15.11 lists valid bits in each register.

Table 15.10 Registers of I/O Ports (100-Pin LQFP) (1 / 2)

Port Symbol	Register Name	Register Symbol	Value after Reset	Address	Access Size
PORT1	Data direction register	DDR	00h	0008 C001h	8
	Data register	DR	00h	0008 C021h	8
	Port register	PORT	Undefined	0008 C041h	8
	Input buffer control register	ICR	00h	0008 C061h	8
PORT2	Data direction register	DDR	00h	0008 C002h	8
	Data register	DR	00h	0008 C022h	8
	Port register	PORT	Undefined	0008 C042h	8
	Input buffer control register	ICR	00h	0008 C062h	8
PORT3	Data direction register	DDR	00h	0008 C003h	8
	Data register	DR	00h	0008 C023h	8
	Port register	PORT	Undefined	0008 C043h	8
	Input buffer control register	ICR	00h	0008 C063h	8
PORT4	Port register	PORT	Undefined	0008 C044h	8
	Input buffer control register	ICR	00h	0008 C064h	8
PORT5	Port register	PORT	Undefined	0008 C045h	8
	Input buffer control register	ICR	00h	0008 C065h	8
PORT6	Port register	PORT	Undefined	0008 C046h	8
	Input buffer control register	ICR	00h	0008 C066h	8
PORT7	Data direction register	DDR	00h	0008 C007h	8
	Data register	DR	00h	0008 C027h	8
	Port register	PORT	Undefined	0008 C047h	8
	Input buffer control register	ICR	00h	0008 C067h	8
PORT8	Data direction register	DDR	00h	0008 C008h	8
	Data register	DR	00h	0008 C028h	8
	Port register	PORT	Undefined	0008 C048h	8
	Input buffer control register	ICR	00h	0008 C068h	8
PORT9	Data direction register	DDR	00h	0008 C009h	8
	Data register	DR	00h	0008 C029h	8
	Port register	PORT	Undefined	0008 C049h	8
	Input buffer control register	ICR	00h	0008 C069h	8
PORTA	Data direction register	DDR	00h	0008 C00Ah	8
	Data register	DR	00h	0008 C02Ah	8
	Port register	PORT	Undefined	0008 C04Ah	8
	Input buffer control register	ICR	00h	0008 C06Ah	8
PORTB	Data direction register	DDR	00h	0008 C00Bh	8
	Data register	DR	00h	0008 C02Bh	8
	Port register	PORT	Undefined	0008 C04Bh	8
	Input buffer control register	ICR	00h	0008 C06Bh	8
PORTD	Data direction register	DDR	00h	0008 C00Dh	8
	Data register	DR	00h	0008 C02Dh	8
	Port register	PORT	Undefined	0008 C04Dh	8
	Input buffer control register	ICR	00h	0008 C06Dh	8

Table 15.10 Registers of I/O Ports (100-Pin LQFP) (2 / 2)

Port Symbol	Register Name	Register Symbol	Value after Reset	Address	Access Size
PORTE	Data direction register	DDR	00h	0008 C00Eh	8
	Data register	DR	00h	0008 C02Eh	8
	Port register	PORT	Undefined	0008 C04Eh	8
	Input buffer control register	ICR	00h	0008 C06Eh	8
IOPORT	Port function register 8	PF8IRQ	00h	0008 C108h	8
	Port function register A	PFAADC	00h	0008 C10Ah	8
	Port function register C	PFCMTU	00h	0008 C10Ch	8
	Port function register D	PFDGPT	00h	0008 C10Dh	8
	Port function register F	PFFSCI	00h	0008 C10Fh	8
	Port function register G	PFGSPI	00h	0008 C110h	8
	Port function register H	PFHSPI	00h	0008 C111h	8
	Port function register J	PFJCAN	00h	0008 C113h	8
	Port function register K	PFKLIN	00h	0008 C114h	8
	Port function register M	PFMPOE	00h	0008 C116h	8
	Port function register N	PFNPOE	00h	0008 C117h	8

Table 15.11 Valid Bits in Each Register (100-Pin LQFP) (1 / 2)

Register Symbol	b7	b6	b5	b4	b3	b2	b1	b0
PORT1.DDR	x	×	×	×	×	×	√	√
PORT2.DDR	×	×	×	√	√	√	√	√
PORT3.DDR	×	×	×	×	√	√	√	√
PORT7.DDR	×	√	√	√	√	√	√	√
PORT8.DDR	×	×	×	×	×	√	√	√
PORT9.DDR	×	√	√	√	√	√	√	√√
PORTA.DDR	×	×	√	√	√	√	√	√
PORTB.DDR	√	√	√	√	√	√	√	√
PORTD.DDR	√	√	√	√	√	√	√	√
PORTE.DDR	×	×	√	√	√	×	√	√
PORT1.DR	×	×	×	×	×	×	√	√
PORT2.DR	×	×	×	√	√	√	√	√
PORT3.DR	×	×	×	×	√	√	√	√
PORT7.DR	×	√	√	√	√	√	√	√
PORT8.DR	×	×	×	×	×	√	√	√
PORT9.DR	×	√	√	√	√	√	√	√
PORTA.DR	×	×	√	√	√	√	√	√
PORTB.DR	√	√	√	√	√	√	√	√
PORTD.DR	√	√	√	√	√	√	√	√
PORTE.DR	×	×	√	√	√	×	√	√
PORT1.PORT	×	×	×	×	×	×	√	√
PORT2.PORT	×	×	×	√	√	√	√	√
PORT3.PORT	×	×	×	×	√	√	√	√
PORT4.PORT	√	√	√	√	√	√	√	√
PORT5.PORT	×	×	√	√	√	√	√	√
PORT6.PORT	×	×	√	√	√	√	√	√
PORT7.PORT	×	√	√	√	√	√	√	√
PORT8.PORT	×	×	×	×	×	√	√	√
PORT9.PORT	×	√	√	√	√	√	√	√
PORTA.PORT	×	×	√	√	√	√	√	√
PORTB.PORT	√	√	√	√	√	√	√	√
PORTD.PORT	√	√	√	√	√	√	√	√
PORTE.PORT	×	×	√	√	√	√	√	√
PORT1.ICR	×	×	×	×	×	×	√	√
PORT2.ICR	×	×	×	√	√	√	√	√
PORT3.ICR	×	×	×	×	√	√	√	√
PORT4.ICR	√	√	√	√	√	√	√	√
PORT5.ICR	×	×	√	√	√	√	√	√
PORT6.ICR	×	×	√	√	√	√	√	√
PORT7.ICR	×	√	√	√	√	√	√	√
PORT8.ICR	×	×	×	×	×	√	√	√
PORT9.ICR	×	√	√	√	√	√	√	√
PORTA.ICR	×	×	√	√	√	√	√	√
PORTB.ICR	√	√	√	√	√	√	√	√

Table 15.11 Valid Bits in Each Register (100-Pin LQFP) (2 / 2)

Register Symbol	b7	b6	b5	b4	b3	b2	b1	b0
PORTD.ICR	√	√	√	√	√	√	√	√
PORTE.ICR	×	×	√	√	√	×	√	√
IOPORT.PF8IRQ	×	×	×	×	√	√	√	√
IOPORT.PFAADC	×	×	×	×	×	×	√	√
IOPORT.PFCMTU	√	√	×	×	×	×	√	√
IOPORT.PFDGPT	×	×	×	×	×	×	×	√
IOPORT.PFFSCI	×	×	×	×	×	√	×	×
IOPORT.PFGSPI	√	√	√	√	√	√	√	×
IOPORT.PFHSPI	×	×	×	×	×	×	√	√
IOPORT.PFJCAN	√	√	×	×	×	×	×	√
IOPORT.PFKLIN	×	×	×	×	×	×	×	√
IOPORT.PFMPOE	×	×	×	√	√	√	√	√
IOPORT.PFNPOE	√	×	×	×	×	×	×	×

√: Enabled bit, x: Disabled bit (Reserved)

15.2.2.1 Data Direction Register (DDR)

Address: PORT1.DDR 0008 C001h, PORT2.DDR 0008 C002h, PORT3.DDR 0008 C003h, PORT7.DDR 0008 C007h, PORT8.DDR 0008 C008h, PORT9.DDR 0008 C009h, PORTA.DDR 0008 C00Ah, PORTB.DDR 0008 C00Bh, PORTD.DDR 0008 C00Dh, PORTE.DDR 0008 C00Eh

	b7	b6	b5	b4	b3	b2	b1	b0
	B7	B6	B5	B4	B3	B2	B1	B0
Value after reset:	0	0	0	0	0	0	0	0

Notes:

1. The lower two bits are valid and the upper six bits are reserved in PORT1.DDR.
   The lower five bits are valid and the upper three bits are reserved in PORT2.DDR.
   The lower four bits are valid and the upper four bits are reserved in PORT3.DDR.
   The lower seven bits are valid and the upper one bit are reserved in PORT7.DDR.
   The lower three bits are valid and the upper four bits are reserved in PORT8.DDR.
   The lower seven bits are valid and the upper one bit is reserved in PORT9.DDR.
   The lower six bits are valid and the upper two bits are reserved in PORTA.DDR.
   Bit 5 to bit 3, bit 1, and bit 0 are valid and bit 7, bit 6, and bit 2 are reserved in PORTE.DDR.
2. The reserved bits are read as 0. The write value should always be 0.

Bit	Symbol	Bit Name	Description	R/W
b0	B0	Pn0 I/O Select (n = 1 to 3, 7 to 9, A, B, D, E)	0: An input pin 1: An output pin	R/W
b1	B1	Pn1 I/O Select		R/W
b2	B2	Pn2 I/O Select		R/W
b3	B3	Pn3 I/O Select		R/W
b4	B4	Pn4 I/O Select		R/W
b5	B5	Pn5 I/O Select		R/W
b6	B6	Pn6 I/O Select		R/W
b7	B7	Pn7 I/O Select		R/W

n = 1 to 3, 7 to 9, A, B, D, E

Each PORTn.DDR is used to select the input or output direction for individual pins of the corresponding port that have been configured to function as general I/O pins.

Each bit of a PORTn.DDR (n = 1 to 3, 7 to 9, A, B, D, E) corresponds to a pin of Pn, and the settings can change from bit to bit.

15.2.2.2 Data Register (DR)

Address: PORT1.DR 0008 C021h, PORT2.DR 0008 C022h, PORT3.DR 0008 C023h, PORT7.DR 0008 C027h, PORT8.DR 0008 C028h, PORT9.DR 0008 C029h, PORTA.DR 0008 C02Ah, PORTB.DR 0008 C02Bh, PORTD.DR 0008 C02Dh, PORTE.DR 0008 C02Eh

	b7	b6	b5	b4	b3	b2	b1	b0
	B7	B6	B5	B4	B3	B2	B1	B0
Value after reset:	0	0	0	0	0	0	0	0

Notes:

1. The lower two bits are valid and the upper six bits are reserved in PORT1.DR.
   The lower five bits are valid and the upper three bits are reserved in PORT2.DR.
   The lower four bits are valid and the upper four bits are reserved in PORT3.DR.
   The lower seven bits are valid and the highest order bit is reserved in PORT7.DR.
   The lower three bits are valid and the upper five bits are reserved in PORT8.DR.
   The lower seven bits are valid and the highest order bit is reserved in PORT9.DR.
   The lower six bits are valid and the upper two bits are reserved in PORTA.DR.
   Bit 5 to bit 3, bit 1, and bit 0 are valid and bit 7, bit 6, and bit 2 are reserved in PORTE.DR.
2. The reserved bits are read as 0. The write value should always be 0.

Bit	Symbol	Bit Name	Description	R/W
b0	B0	Pn0 Output Data Store (n=1 to 3, 7 to 9, A, B, D, E)	Output data are stored.	R/W
b1	B1	Pn1 Output Data Store		R/W
b2	B2	Pn2 Output Data Store		R/W
b3	B3	Pn3 Output Data Store		R/W
b4	B4	Pn4 Output Data Store		R/W
b5	B5	Pn5 Output Data Store		R/W
b6	B6	Pn6 Output Data Store		R/W
b7	B7	Pn7 Output Data Store		R/W

n = 1 to 3, 7 to 9, A, B, D, E

Each PORTn.DR (n = 1 to 3, 7 to 9, A, B, D, E) stores the output data from the individual pins of the corresponding port used as a general I/O port.

15.2.2.3 Port Register (PORT)

Address: PORT1.PORT 0008 C041h, PORT2.PORT 0008 C042h, PORT3.PORT 0008 C043h, PORT4.PORT 0008 C044h, PORT5.PORT 0008 C045h, PORT6.PORT 0008 C046h, PORT7.PORT 0008 C047h, PORT8.PORT 0008 C048h, PORT9.PORT 0008 C049h, PORTA.PORT 0008 C04Ah, PORTB.PORT 0008 C04Bh, PORTD.PORT 0008 C04Dh, PORTE.PORT 0008 C04Eh

	b7	b6	b5	b4	b3	b2	b1	b0
	B7	B6	B5	B4	B3	B2	B1	B0
Value after reset:	x	x	x	x	x	x	x	x

Notes:

1. The lower two bits are valid and the upper six bits are reserved in PORT1.PORT.
   The lower five bits are valid and the upper three bits are reserved in PORT2.PORT.
   The lower four bits are valid and the upper four bits are reserved in PORT3.PORT.
   The lower six bits are valid and the upper two bits are reserved in PORT5.PORT.
   The lower six bits are valid and the upper two bits are reserved in PORT6.PORT.
   The lower seven bits are valid and the highest order bit is reserved in PORT7.PORT.
   The lower three bits are valid and the upper five bits are reserved in PORT8.PORT
   The lower seven bits are valid and the highest order bit is reserved in PORT9.PORT.
   The lower six bits are valid and the upper two bits are reserved in PORTA.PORT.
   The lower six bits are valid and the upper two bits are reserved in PORTE.PORT.
2. The reserved bits are read as 1. Writing to these bits has no effect.

Bit	Symbol	Bit Name	Description	R/W
b0	B0	Pn0 (n = 1 to 9, A, B, D, E)	Individual pin states of the corresponding port are reflected.	R
b1	B1	Pn1		R
b2	B2	Pn2		R
b3	B3	Pn3		R
b4	B4	Pn4		R
b5	B5	Pn5		R
b6	B6	Pn6		R
b7	B7	Pn7		R

n = 1 to 9, A, B, D, E

PORT reflects individual pin states of the corresponding port.
When a PORTn.PORT (n = 1 to 9, A, B, D, E, G) is read, the corresponding pin states are read out to here.

15.2.2.4 Input Buffer Control Register (ICR)

Address: PORT1.ICR 0008 C061h, PORT2.ICR 0008 C062h, PORT3.ICR 0008 C063h, PORT4.ICR 0008 C064h, PORT5.ICR 0008 C065h, PORT6.ICR 0008 C066h, PORT7.ICR 0008 C067h, PORT8.ICR 0008 C068h, PORT9.ICR 0008 C069h, PORTA.ICR 0008 C06Ah, PORTB.ICR 0008 C06Bh, PORTD.ICR 0008 C06Dh, PORTE.ICR 0008 C06Eh

	b7	b6	b5	b4	b3	b2	b1	b0
	B7	B6	B5	B4	B3	B2	B1	B0
Value after reset:	0	0	0	0	0	0	0	0

Notes:
1. The lower two bits are valid and the upper six bits are reserved in PORT1.ICR.
   The lower five bits are valid and the upper three bits are reserved in PORT2.ICR.
   The lower four bits are valid and the upper four bits are reserved in PORT3.ICR.
   The lower six bits are valid and the upper two bits are reserved in PORT5.ICR.
   The lower six bits are valid and the upper two bits are reserved in PORT6.ICR.
   The lower seven bits are valid and the highest order bit is reserved in PORT7.ICR.
   The lower three bits are valid and the upper five bits are reserved in PORT8.ICR.
   The lower seven bits are valid and the highest order bit is reserved in PORT9.ICR.
   The lower six bits are valid and the upper two bits are reserved in PORTA.ICR.
   Bit 5 to bit 3, bit 1, and bit 0 are valid and bit 7, bit 6, and bit 2 are reserved in PORTE.ICR.
2. The reserved bits are read as 0. The write value should always be 0.

Bit	Symbol	Bit Name	Description	R/W
b0	B0*1	Pn0 Input Buffer Control (n = 1 to 9, A, B, D, E)	0: The input buffer for the corresponding pin is disabled. 1: The input buffer for the corresponding pin is enabled.	R/W
b1	B1*1	Pn1 Input Buffer Control		R/W
b2	B2*1	Pn2 Input Buffer Control		R/W
b3	B3*1	Pn3 Input Buffer Control		R/W
b4	B4*1	Pn4 Input Buffer Control		R/W
b5	B5*1	Pn5 Input Buffer Control		R/W
b6	B6*1	Pn6 Input Buffer Control		R/W
b7	B7*1	Pn7 Input Buffer Control		R/W

n = 1 to 9, A, B, D, E

Note 1. For pins being used as input pins for peripheral modules, set the corresponding bits to 1. Set the bits corresponding to pins that are not being used for their input functions or are being used as analog input pins to 0.

Each PORTn.ICR controls the input buffers for the individual pins of the corresponding port.

Each bit of a PORTn.ICR (n = 1 to 9, A, B, D, E) corresponds to a pin of Pn, and the settings can change from bit to bit. When to be used as an input pin for the peripheral module, the input buffer for the corresponding pin should be enabled beforehand by setting the PORTn.ICR bit to 1. If this register is used as an input pin for the peripheral module while the PORTn.ICR bit is 0, the input signal to the peripheral module is fixed high.

When a Pn.PORT register is read, the pin states of the corresponding port are read out regardless of the values in PORTn.ICR. For bits where the value in PORTn.ICR is 0, however, the value may not reflect the pin state on the corresponding peripheral module side.

Changes in the settings of a PORTn.ICR may generate edges internally, depending on the pin state. For this reason, change the settings of PORTn.ICR while the corresponding input pins are not in use. For example, in the case of IRQi (i = 0 to 7) inputs, change settings of the corresponding PORTn.ICR with interrupts disabled by clearing the IR flag in IRi (i = 64 to 71 ("i" shows an interrupt vector number of the IRQ)) of the interrupt controller (ICU) to 0, and then enable the corresponding interrupts. If a change to a PORTn.ICR setting does generate an edge, negate the edge.

15.2.2.5 Port Function Register 8 (PF8IRQ)

Address: 0008 C108h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	ITS1[1:0]		ITS0[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1 to b0	ITS0[1:0]	IRQ0 Pin Select	b1 b0 0 0:P10 is designated as the IRQ0-A input pin. 0 1:PE5 is designated as the IRQ0-B input pin. 1 0:Setting prohibited 1 1:Setting prohibited	R/W
b3 to b2	ITS1[1:0]	IRQ1 Pin Select	b3 b2 0 0:P11 is designated as the IRQ1-A input pin. 0 1:PE4 is designated as the IRQ1-B input pin. 1 0:Setting prohibited 1 1:Setting prohibited	R/W
b7 to b4	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

PF8IRQ is used to select pins for IRQ0 to IRQ1 inputs.

ITSi Bit (IRQi Pin Select) (i = 0 and 1)

Each bit selects a pin for an IRQi input.

15.2.2.6 Port Function Register A (PFAADC)

Address: 0008 C10Ah

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	ADTRG1S	ADTRG0S
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	ADTRG0S	ADTRG0# Input Select	0:PA4 is designated as the ADTRG0#-A input pin. 1:P20 is designated as the ADTRG0#-B input pin.	R/W
b1	ADTRG1S	ADTRG1# Input Select	0:PA5 is designated as the ADTRG1#-A input pin. 1:P21 is designated as the ADTRG1#-B input pin.	R/W
b7-b2	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

PFAADC is used to select the ADTRG0# and ADTRG1# pins.

ADTRGnS Bit (ADTRGn# Input Select) (n=0 and 1)

This bit selects a pin for an ADTRGn# input.

15.2.2.7 Port Function Register C (PFCMTU)

Address: 008 C10Ch

	b7	b6	b5	b4	b3	b2	b1	b0
	TCLKS[1:0]		—	—	—	—	MTUS1	MTUS0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	MTUS0	MTU3 Pin Select 0	0:PB3 is designated as the MTIOC0A-A pin. 1:P31 is designated as the MTIOC0A-B pin.	R/W
b1	MTUS1	MTU3 Pin Select 1	0:PB2 is designated as the MTIOC0B-A pin. 1:P30 is designated as the MTIOC0B-B pin.	R/W
b5 to b2	—	(Reserved)	These bits are always read as 0. The write value should always be 0.	R/W
b7, b6	TCLKS[1:0]	MTCLK Pin Select	b7 b6 0 0:P33 is designated as the MTCLKA-A pin. P32 is designated as the MTCLKB-A pin. P31 is designated as the MTCLKC-A pin. P30 is designated as the MTCLKD-A pin. 0 1:P21 is designated as the MTCLKA-B pin. P20 is designated as the MTCLKB-B pin. P11 is designated as the MTCLKC-B pin. P10 is designated as the MTCLKD-B pin. 1 0:PE4 is designated as the MTCLKC-C pin. PE3 is designated as the MTCLKD-C pin. (MTCLKA pin and MTCLKB pins cannot be selected.) 1 1:Setting prohibited	R/W

PFCMTU is used to select pins for MTU3.

MTUSi Bit (MTU3 Pin Select) (i = 0 and 1)

Each bit selects a pin for an MTU3 input/output.

TCLKS[1:0] Bit (MTCLK Pin Select)

This bit selects a pin for a MTCLK input of the MTU3.

15.2.2.8 Port Function Register D (PFDGPT)

Address: 0008 C10Dh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	GPTS
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	GPTS	GPT Pin Select	0:P71 is designated as the GTIOC0A-A pin. P74 is designated as the GTIOC0B-A pin. P72 is designated as the GTIOC1A-A pin. P75 is designated as the GTIOC1B-A pin. P73 is designated as the GTIOC2A-A pin. P76 is designated as the GTIOC2B-A pin. 1:PD7 is designated as the GTIOC0A-B pin. PD6 is designated as the GTIOC0B-B pin. PD5 is designated as the GTIOC1A-B pin. PD4 is designated as the GTIOC1B-B pin. PD3 is designated as the GTIOC2A-B pin. PD2 is designated as the GTIOC2B-B pin.	R/W
b7 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

PFDGPT is used to select a pin for GPT.

GPTS Bit (GPT I/O Pin Select)

Each bit selects a pin for a GPT input/output.

15.2.2.9 Port Function Register F (PFFSCI)

Address: 0008 C10Fh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	SCI2S	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1 to b0	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b2	SCI2S	SCI2I/O Pin Select	0:PB6 is designated as the RXD2-A pin. PB7 is designated as the SCK2-A pin. PB5 is designated as the TXD2-A pin. 1:P80 is designated as the RXD2-B pin. P82 is designated as the SCK2-B pin. P81 is designated as the TXD2-B pin.	R/W
b7 to b3	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

PFFSCI is used to select pins for SCI.

SCI2S Bit (SCI2 I/O Pin Select)

Each bit selects a pin for an SCI channel-2 input/output.

15.2.2.10 Port Function Register G (PFGSPI)

Address: 0008 C110h

	b7	b6	b5	b4	b3	b2	b1	b0
	SSL3E	SSL2E	SSL1E	SSL0E	MISOE	MOSIE	RSPCKE	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b1	RSPCKE	RSPCK Output Enable	0:RSPCK pin is disabled. 1:RSPCK pin is enabled.	R/W
b2	MOSIE	MOSI Output Enable	0:MOSI pin is disabled. 1:MOSI pin is enabled.	R/W
b3	MISOE	MISO Output Enable	0:MISO pin is disabled. 1:MISO pin is enabled.	R/W
b4	SSL0E	SSL0 Output Enable	0:SSL0 pin is disabled. 1:SSL0 pin is enabled.	R/W
b5	SSL1E	SSL1 Output Enable	0:SSL1 pin is disabled. 1:SSL1 pin is enabled.	R/W
b6	SSL2E	SSL2 Output Enable	0:SSL2 pin is disabled. 1:SSL2 pin is enabled.	R/W
b7	SSL3E	SSL3 Output Enable	0:SSL3 pin is disabled. 1:SSL3 pin is enabled.	R/W

PFGSPI is used to select I/O pins for RSPI.

RSPCKE Bit (RSPCK Output Enable)

This bit enables or disables the output of the RSPCK pin. Set this bit to 1 to use the RSPCK pin.

MOSIE Bit (MOSI Output Enable)

This bit enables or disables the output of the MOSI pin. Set this bit to 1 to use the MOSI pin.

MISOE Bit (MISO Output Enable)

This bit enables or disables the output of the MISO pin. Set this bit to 1 to use the MISO pin.

SSL0E Bit (SSL0 Output Enable)

This bit enables or disables the output of the SSL0 pin. Set this bit to 1 to use the SSL0 pin.

SSL1E Bit (SSL1 Output Enable)

This bit enables or disables the output of the SSL1 pin. Set this bit to 1 to use the SSL1 pin.

SSL2E Bit (SSL2 Output Enable)

This bit enables or disables the output of the SSL2 pin. Set this bit to 1 to use the SSL2 pin.

SSL3E Bit (SSL3 Output Enable)

This bit enables or disables the output of the SSL3 pin. Set this bit to 1 to use the SSL3 pin.

15.2.2.11 Port Function Register H (PFHSPI)

Address: 0008 C10Fh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	RSPIS[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1 to b0	RSPIS[1:0]	RSPI Pin Select	b1 b0 0 0:P22 is designated as the MISO-A pin. P23 is designated as the MOSI-A pin. P24 is designated as the RSPCK-A pin. P30 is designated as the SSL0-A pin. P31 is designated as the SSL1-A pin. P32 is designated as the SSL2-A pin. P33 is designated as the SSL3-A pin. 0 1:PA5 is designated as the MISO-B pin. PB0 is designated as the MOSI-B pin. PA4 is designated as the RSPCK-B pin. PA3 is designated as the SSL0-B pin. PA2 is designated as the SSL1-B pin. PA1 is designated as the SSL2-B pin. PA0 is designated as the SSL3-B pin. 1 0:PD1 is designated as the MISO-C pin. PD2 is designated as the MOSI-C pin. PD0 is designated as the RSPCK-C pin. PD6 is designated as the SSL0-C pin. PD7 is designated as the SSL1-C pin. PE0 is designated as the SSL2-C pin. PE1 is designated as the SSL3-C pin. 1 1:Setting prohibited	R/W
b7 to b2	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

PFHSPI is used to select I/O pins for RSPI channel.

RSPIS[1:0] Bit (RSPI Pin Select)

This bit selects a pin for an RSPI input/output.

As an enable bit is provided for each RSPI input/output pin, the input/output pin is selectable while the corresponding enable bit is 1. Otherwise, the pin cannot be selected.

15.2.2.12 Port Function Register J (PFJCAN)

Address: 0008 C113h

	b7	b6	b5	b4	b3	b2	b1	b0
	CANS[1:0]		—	—	—	—	—	CANE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	CANE	CAN Pin Enable	0: The CTX and CRX pins are disabled. 1: The CTX and CRX pins are enabled.	R/W
b5 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7 to b6	CANS[1:0]	CAN Pin Select	b7 b6 0 0: PB5 is designated as the CTX-A pin. PB6 is designated as the CRX-A pin. 0 1: P23 is designated as the CTX-B pin. P22 is designated as the CRX-B pin. 1 0: PE0 is designated as the CRX-C pin. PD7 is designated as the CTX-C pin. 1 1: Setting prohibited	R/W

PFJCAN is used to select I/O pins for the CAN.

CANE Bit (CAN Pin Enable)

This bit enables or disables the CAN pin. Set this bit to 1 to use the CAN pin.

CANS[1:0] Bit (CAN Pin Select)

These bits select I/O pins for the CAN.

15.2.2.13 Port Function Register K (PFKLIN)

Address: 0008 C114h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	LINE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	LINE	LIN Pin Enable	0:LTX and LRX pins are disabled. 1:LTX and LRX pins are enabled.	R/W
b7 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

PFKLIN is used to set I/O pins for the LIN.

LINE Bit (LIN Pin Enable)

This bit enables or disables the LIN pin. Set this bit to 1 to use the LIN pin.

15.2.2.14 Port Function Register M (PFMPOE)

Address: 0008 C116h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	POE11E	POE10E	POE8E	POE4E	POE0E
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	POE0E	POE0# Input Enable	0:Designated as an I/O port pin 1:Designated as the POEn# input pin (n = 0, 4, 8, 10, 11)	R/W*1
b1	POE4E	POE4# Input Enable		R/W*1
b2	POE8E	POE8# Input Enable		R/W*1
b3	POE10E	POE10# Input Enable		R/W*1
b4	POE11E	POE11# Input Enable		R/W*1
b7 to b5	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

Note 1. The first round of writing after a reset is enabled; though subsequent writing is not allowed.

PFMPOE enables or disables POEn# input pins.
To prevent the error in the system, be sure to write to this register after a reset.
The first round of writing after a reset is only enabled

POEnE Bit (POEn# Input Enable) (n = 0, 4, 8, 10, 11)

Each bit enables or disables the corresponding POEn# input.
To use POEn#, set the corresponding POEnE bit to 1.

15.2.2.15 Port Function Register N (PFNPOE)

Address: 0008 C117h

	b7	b6	b5	b4	b3	b2	b1	b0
	POE10S	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b6 to b0	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7	POE10S	POE10# Input Select	0:PE2 is designated as the POE10#-A input pin. 1:PE4 B is designated as the POE10# input pin.	R/W*1

Note 1. The first round of writing after a reset is enabled; though subsequent writing is not allowed.

PFNPOE enables or disables POEn# input pins.
To prevent the error in the system, be sure to write to this register after a reset.
The first round of writing after a reset is only enabled.

POE10S Bit (POE10# Input Select)

This bit select input pins for the POE10#.

15.2.3 Settings of Ports

When individual pins for peripheral modules are enabled, the settings for each port are modified.
An input pin for the peripheral module is specified independently by the peripheral module. To use an input pin for the peripheral module, the corresponding bit in the input buffer control register (PORTn.ICR) should be set to 1 to enable the input buffer, except for the port register read, NMI, and POEn# pin inputs.
The pins that function as output pins and I/O pins should be enabled for respective peripheral modules. If a conflict occurs among the output signal enable settings for peripheral modules, that are multiplexed to the same port, the priority will be handled according to the port-multiplexed priority.
Table 15.12 lists the port-multiplexed priority for peripheral modules.

Table 15.12 Port-Multiplexed Priority for Peripheral Modules (100-Pin LQFP)

Priority		Module Name	Output Pins
High	1	RSPI	RSPCK, MOSI, MISO, SSL0 to SSL3
↑	2	CAN	CTX
	3	LIN	LTX
	4	MTU0 to MTU7	MTIOC0A, MTIOC0B, MTIOC0C, MTIOC0D, MTIOC1A, MTIOC1B, MTIOC2A, MTIOC2B, MTIOC3A, MTIOC3B, MTIOC3C, MTIOC3D, MTIOC4A, MTIOC4B, MTIOC4C, MTIOC4D, MTIOC6A, MTIOC6B, MTIOC6C, MTIOC6D, MTIOC7A, MTIOC7B, MTIOC7C, MTIOC7D
	5	GPT0 to GPT3	GTIOC0A, GTIOC0B, GTIOC1A, GTIOC1B, GTIOC2A, GTIOC2B, GTIOC3A, GTIOC3B
	6	SCI0 to SCI2	SCK0 to SCK2, TXD0 to TXD2
	7	RIIC	SCL, SDA
Low	8	IOPORT	P10 to P11, P20 to P24, P30 to P33, P70 to P76, P80 to P82, P90 to P96, PA0 to PA5, PB0 to PB7, PD0 to PD7, PE0 to PE1, PE3 to PE5

15.2.4 List of Output Enable Settings

Table 15.13 lists the output enable settings for each port.
For details on the applicable output signals, see descriptions of the registers for each peripheral module.
Setting the port function register changes the functions of peripheral-module pins with names ending in A to C.

Table 15.13 Output Enable Settings for Each Port (100-Pin LQFP) (1 / 5)

Port	Module Name	Output Signal Name	Port Function Register Settings	Peripheral Module Settings
P10	PORT1	P10		PORT1.DDR.B0 = 1
P11	PORT1	P11		PORT1.DDR.B1 = 1
P20	PORT1	P20		PORT2.DDR.B0 = 1
P21	PORT1	P21		PORT2.DDR.B1 = 1
P22	RSPI	MISO-A	PFGSPI.MISOE = 1 PFHSPI.RSPIS[1:0] = 00	(In addition to the pin enable setting, input/output switching function for the peripheral module is provided.)
	PORT2	P22		PORT2.DDR.B2 = 1
P23	RSPI	MOSI-A	PFGSPI.MOSIE = 1 PFHSPI.RSPIS[1:0] = 00	(In addition to the pin enable setting, input/output switching function for the peripheral module is provided.)
	CAN	CTX-B	PFJCAN.CANE = 1 PFJCAN.CANS[1:0] = 01	(The signal output state is specified by the peripheral module settings.)
	LIN	LTX	PFKLIN.LINE = 1	(The signal output state is specified by the peripheral module settings.)
	PORT2	P23		PORT2.DDR.B3 =1
P24	RSPI	RSPCK-A	PFGSPI.RSPCKE =1 PFHSPI.RSPIS[1:0] = 00	(In addition to the pin enable setting, input/output switching function for the peripheral module is provided.)
	PORT2	P24		PORT2.DDR.B4 = 1
P30	RSPI	SSL0-A	PFGSPI.SSL0E = 1 PFHSPI.RSPIS[1:0] = 00	(In addition to the pin enable setting, input/output switching function for the peripheral module is provided.)
	MTU0	MTIOC0B-B	PFCMTU.MTUS1 = 1	(The signal output state is specified by the peripheral module settings.)
	PORT3	P30		PORT3.DDR.B0 = 1
P31	RSPI	SSL1-A	PFGSPI.SSL1E = 1 PFHSPI.RSPIS[1:0] = 00	(The signal output state is specified by the peripheral module settings.)
	MTU0	MTIOC0A-B	PFCMTU.MTUS0 = 1	(The signal output state is specified by the peripheral module settings.)
	PORT3	P31		PORT3.DDR.B1=1
P32	RSPI	SSL2-A	PFGSPI.SSL2E = 1 PFHSPI.RSPIS[1:0] = 00	(The signal output state is specified by the peripheral module settings.)
	MTU3	MTIOC3C		(The signal output state is specified by the peripheral module settings.)
	PORT3	P32		PORT3.DDR.B2 = 1
P33	RSPI	SSL3-A	PFGSPI.SSL3E =1 PFHSPI.RSPIS[1:0] = 00	(The signal output state is specified by the peripheral module settings.)
	MTU3	MTIOC3A		(The signal output state is specified by the peripheral module settings.)
	PORT3	P33		PORT3.DDR.B3 = 1
P70	PORT7	P70		PORT7.DDR.B0 = 1
P71	MTU3	MTIOC3B		(The signal output state is specified by the peripheral module settings.)
	GPT0	GTIOC0A-A	PFDGPT.GPTS = 0	(The signal output state is specified by the peripheral module settings.)
	PORT7	P71		PORT7.DDR.B1 = 1

Table 15.13 Output Enable Settings for Each Port (100-Pin LQFP) (2 / 5)

Port	Module Name	Output Signal Name	Port Function Register Settings	Peripheral Module Settings
P72	MTU4	MTIOC4A		(The signal output state is specified by the peripheral module settings.)
	GPT1	GTIOC1A-A	PFDGPT.GPTS = 0	(The signal output state is specified by the peripheral module settings.)
	PORT7	P72		PORT7.DDR.B2 = 1
P73	MTU4	MTIOC4B		(The signal output state is specified by the peripheral module settings.)
	GPT2	GTIOC2A-A	PFDGPT.GPTS = 0	(The signal output state is specified by the peripheral module settings.)
	PORT7	P73		PORT7.DDR.B3 = 1
P74	MTU3	MTIOC3D		(The signal output state is specified by the peripheral module settings.)
	GPT0	GTIOC0B-A	PFDGPT.GPTS = 0	(The signal output state is specified by the peripheral module settings.)
	PORT7	P74		PORT7.DDR.B4 = 1
P75	MTU4	MTIOC4C		(The signal output state is specified by the peripheral module settings.)
	GPT1	GTIOC1B-A	PFDGPT.GPTS = 0	(The signal output state is specified by the peripheral module settings.)
	PORT7	P75		PORT7.DDR.B5 = 1
P76	MTU4	MTIOC4D		(The signal output state is specified by the peripheral module settings.)
	GPT2	GTIOC2B-A	PFDGPT.GPTS = 0	(The signal output state is specified by the peripheral module settings.)
	PORT7	P76		PORT7.DDR.B6 = 1
P80	PORT8	P80		PORT8.DDR.B0 = 1
P81	SCI2	TXD2-B	PFFSCI.SCI2S = 1	SCI2.SCR.TE = 1
	PORT8	P81		PORT8.DDR.B1 = 1
P82	SCI2	SCK2-B	PFFSCI.SCI2S = 1	When SCI2.SCMR.SMIF = 1: While SMR.GM = 0, SCR.CKE[1:0] = 01 or SMR.GM = 1, SCR.TE = 1 or SCR.RE = 1 When SCI2.SCMR.SMIF = 0: While SMR.CM = 0, SCR.CKE[1:0] = 01 or SMR.CM = 1, SCR.CKE[1] = 0, SCR.TE = 1 or SCR.RE = 1
	PORT8	P82		PORT8.DDR.B2 = 1
P90	MTU7	MTIOC7D		(The signal output state is specified by the peripheral module settings.)
	PORT9	P90		PORT9.DDR.B0 = 1
P91	MTU7	MTIOC7C		(The signal output state is specified by the peripheral module settings.)
	PORT9	P91		PORT9.DDR.B1 = 1
P92	MTU6	MTIOC6D		(The signal output state is specified by the peripheral module settings.)
	PORT9	P92		PORT9.DDR.B2 = 1
P93	MTU7	MTIOC7B		(The signal output state is specified by the peripheral module settings.)
	PORT9	P93		PORT9.DDR.B3 = 1
P94	MTU7	MTIOC7A		(The signal output state is specified by the peripheral module settings.)
	PORT9	P94		PORT9.DDR.B4 = 1

Table 15.13 Output Enable Settings for Each Port (100-Pin LQFP) (3 / 5)

Port	Module Name	Output Signal Name	Port Function Register Settings	Peripheral Module Settings
P95	MTU6	MTIOC6B		(The signal output state is specified by the peripheral module settings.)
	PORT9	P95		PORT9.DDR.B5 = 1
P96	PORT9	P96		PORT9.DDR.B6 = 1
PA0	RSPI	SSL3-B	PFGSPI.SSL3E = 1 PFHSPI.RSPIS[1:0] = 01	(The signal output state is specified by the peripheral module settings.)
	MTU6	MTIOC6C		(The signal output state is specified by the peripheral module settings.)
	PORTA	PA0		PORTA.DDR.B0 = 1
PA1	RSPI	SSL2-B	PFGSPI.SSL2E = 1 PFHSPI.RSPIS[1:0] = 01	(The signal output state is specified by the peripheral module settings.)
	MTU6	MTIOC6A		(The signal output state is specified by the peripheral module settings.)
	PORTA	PA1		PORTA.DDR.B1 = 1
PA2	RSPI	SSL1-B	PFGSPI.SSL1E = 1 PFHSPI.RSPIS[1:0] = 01	(The signal output state is specified by the peripheral module settings.)
	MTU2	MTIOC2B		(The signal output state is specified by the peripheral module settings.)
	PORTA	PA2		PORTA.DDR.B2 = 1
PA3	RSPI	SSL0-B	PFGSPI.SSL0E = 1 PFHSPI.RSPIS[1:0] = 01	(In addition to the pin enable setting, input/output switching function for the peripheral module is provided.)
	MTU2	MTIOC2A		(The signal output state is specified by the peripheral module settings.)
	PORTA	PA3		PORTA.DDR.B3 = 1
PA4	RSPI	RSPCK-B	PFGSPI.RSPCKE = 1 PFHSPI.RSPIS[1:0] = 01	(In addition to the pin enable setting, input/output switching function for the peripheral module is provided.)
	MTU1	MTIOC1B		(The signal output state is specified by the peripheral module settings.)
	PORTA	PA4		PORTA.DDR.B4 = 1
PA5	RSPI	MISO-B	PFGSPI.MISOE = 1 PFHSPI.RSPIS[1:0] = 01	(In addition to the pin enable setting, input/output switching function for the peripheral module is provided.)
	MTU1	MTIOC1A		(The signal output state is specified by the peripheral module settings.)
	PORTA	PA5		PORTA.DDR.B5 = 1
PB0	RSPI	MOSI-B	PFGSPI.MOSIE = 1 PFHSPI.RSPIS[1:0] = 01	(In addition to the pin enable setting, input/output switching function for the peripheral module is provided.)
	MTU0	MTIOC0D		(The signal output state is specified by the peripheral module settings.)
	PORTB	PB0		PORTB.DDR.B0 = 1
PB1	MTU0	MTIOC0C		(The signal output state is specified by the peripheral module settings.)
	RIIC	SCL		RIIC.ICCR1.ICE = 1
	PORTB	PB1		PORTB.DDR.B1 = 1
PB2	MTU0	MTIOC0B-A	PFCMTU.MTUS1 = 0	(The signal output state is specified by the peripheral module settings.)
	SCI0	TXD0		SCI0.SCR.TE = 1
	RIIC	SDA		RIIC.ICCR1.ICE = 1
	PORTB	PB2		PORTB.DDR.B2 = 1

Table 15.13 Output Enable Settings for Each Port (100-Pin LQFP) (4 / 5)

Port	Module Name	Output Signal Name	Port Function Register Settings	Peripheral Module Settings
PB3	MTU0	MTIOC0A-A	PFCMTU.MTUS0 = 0	(The signal output state is specified by the peripheral module settings.)
	SCI0	SCK0		When SCI0.SCMR.SMIF = 1: While SMR.GM = 0, SCR.CKE[1:0] = 01 or SMR.GM = 1, SCR.TE = 1 or SCR.RE = 1 When SCI0.SCMR.SMIF = 0: While SMR.CM = 0, SCR.CKE[1:0] = 01 or SMR.CM = 1, SCR.CKE[1] = 0, SCR.TE = 1 or SCR.RE = 1
	PORTB	PB3		PORTB.DDR.B3 = 1
PB4	PORTB	PB4		PORTB.DDR.B4 = 1
PB5	CAN	CTX-A	PFJCAN.CANE = 1 PFJCAN.CANS[1:0] = 00	(The signal output state is specified by the peripheral module settings.)
	SCI2	TXD2-A	PFFSCI.SCI2S = 0	SCI2.SCR.TE = 1
	PORTB	PB5		PORTB.DDR.B5 = 1
PB6	PORTB	PB6		PORTB.DDR.B6 = 1
PB7	SCI2	SCK2-A	PFFSCI.SCI2S = 0	When SCI2.SCMR.SMIF =1: While SMR.GM = 0, SCR.CKE[1:0] = 01 or SMR.GM = 1, SCR.TE = 1 or SCR.RE = 1 When SCI2.SCMR.SMIF = 0: While SMR.CM = 0, SCR.CKE[1:0] = 01 or SMR.CM = 1, SCR.CKE[1] = 0, SCR.TE = 1 or SCR.RE = 1
	PORTB	PB7		PORTB.DDR.B7 = 1
PD0	RSPI	RSPCK-C	PFGSPI.RSPCKE = 1 PFHSPI.RSPIS[1:0] = 10	(In addition to the pin enable setting, input/output switching function for the peripheral module is provided.)
	GPT3	GTIOC3B		(The signal output state is specified by the peripheral module settings.)
	PORTD	PD0		PORTD.DDR.B0 = 1
PD1	RSPI	MISO-C	PFGSPI.MISOE = 1 PFHSPI.RSPIS[1:0] = 10	(In addition to the pin enable setting, input/output switching function for the peripheral module is provided.)
	GPT3	GTIOC3A		(The signal output state is specified by the peripheral module settings.)
	PORTD	PD1		PORTD.DDR.B1 = 1
PD2	RSPI	MOSI-C	PFGSPI.MISOE = 1 PFHSPI.RSPIS[1:0] = 10	(In addition to the pin enable setting, input/output switching function for the peripheral module is provided.)
	GPT2	GTIOC2B-B	PFDGPT.GPTS = 1	(The signal output state is specified by the peripheral module settings.)
	PORTD	PD2		PORTD.DDR.B2 = 1
PD3	GPT2	GTIOC2A-B	PFDGPT.GPTS = 1	(The signal output state is specified by the peripheral module settings.)
	SCI1	TXD1		SCI1.SCR.TE = 1
	PORTD	PD3		PORTD.DDR.B3 = 1
PD4	GPT1	GTIOC1B-B	PFDGPT.GPTS = 1	(The signal output state is specified by the peripheral module settings.)
	SCI1	SCK1		When SCI1.SCMR.SMIF = 1: While SMR.GM = 0, SCR.CKE[1:0] = 01 or SMR.GM = 1, SCR.TE = 1 or SCR.RE = 1 When SCI1.SCMR.SMIF = 0: While SMR.CM = 0, SCR.CKE[1:0] = 01 or SMR.CM = 1, SCR.CKE[1] = 0, SCR.TE = 1 or SCR.RE = 1
	PORTD	PD4		PORTD.DDR.B4 = 1
PD5	GPT1	GTIOC1A-B	PFDGPT.GPTS = 1	(The signal output state is specified by the peripheral module settings.)
	PORTD	PD5		PORTD.DDR.B5 = 1

Table 15.13 Output Enable Settings for Each Port (100-Pin LQFP) (5 / 5)

Port	Module Name	Output Signal Name	Port Function Register Settings	Peripheral Module Settings
PD6	RSPI	SSL0-C	PFGSPI.SSL0E = 1 PFHSPI.RSPIS[1:0] = 10	(In addition to the pin enable setting, input/output switching function for the peripheral module is provided.)
	GPT0	GTIOC0B-B	PFDGPT.GPTS = 1	(The signal output state is specified by the peripheral module settings.)
	PORTD	PD6		PORTD.DDR.B6 = 1
PD7	RSPI	SSL1-C	PFGSPI.SSL1E = 1 PFHSPI.RSPIS[1:0] = 10	(The signal output state is specified by the peripheral module settings.)
	CAN	CTX-C	PFJCAN.CANE = 1 PFJCAN.CANS[1:0] = 10	(The signal output state is specified by the peripheral module settings.)
	GPT0	GTIOC0A-B	PFDGPT.GPTS = 1	(The signal output state is specified by the peripheral module settings.)
	PORTD	PD7		PORTD.DDR.B7 = 1
PE0	RSPI	SSL2-C	PFGSPI.SSL2E = 1 PFHSPI.RSPIS[1:0] = 10	(The signal output state is specified by the peripheral module settings.)
	PORTE	PE0		PE.DDR.B0 = 1
PE1	RSPI	SSL3-C	PFGSPI.SSL3E = 1 PFHSPI.RSPIS[1:0] = 10	(The signal output state is specified by the peripheral module settings.)
	PORTE	PE1		PORTE.DDR.B1 = 1
PE3	PORTE	PE3		PORTE.DDR.B3 = 1
PE4	PORTE	PE4		PORTE.DDR.B4 = 1
PE5	PORTE	PE5		PORTE.DDR.B5 = 1

15.2.5 Treatment of Unused Pins

The treatment of unused pins is listed in Table 15.14.

Table 15.14 Treatment of Unused Pins (100-Pin LQFP)

Pin Name	Treatment
EMLE	Connect this pin to Vss via a pull-down resistor.
MD1, MD0	(Always used as mode pins)
MDE	(Always used as mode pins)
RES#	Connect this pin to Vcc via a pull-up resistor.
PE2/NMI/POE10#-A	Connect this pin to Vcc via a pull-up resistor.
EXTAL	(Always used as a clock pin)
XTAL	Leave these pins open.
Ports 1 to 3, 7 to 9, A, B, D, E	• Connect these pins to Vcc via a pull-up resistor or to Vss via a pull-down resistor. • These pins can be left while PORTn.ICR is in the initial state (the input buffer disabled)*1.
Ports 4	• Connect these pins to AVCC0 via a pull-up resistor or to AVSS0 via a pull-down resistor. • These pins can be left while PORTn.ICR is in the initial state (the input buffer disabled)*1.
Ports 5 to 6	• Connect these pins to AVCC via a pull-up resistor or to AVSS via a pull-down resistor • These pins can be left while PORTn.ICR is in the initial state (the input buffer disabled)*1.
VREFH0	Connect this pin to AVCC0
VREFL0	Connect this pin to AVSS0
VREF	Connect this pin to AVCC

Note 1. Do not change the initial value of PORTn.ICR. Changing the initial value may generate shoot-through current.

15.3 I/O Port [for 80-Pin LQFP]

The RX62T Group (80-Pin LQFP) has 11 I/O ports (ports 1 to 4, 6, 7, 9, A, B, D, E), which handle 44 I/O pins.

15.3.1 Overview

Table 15.15 gives the specifications of the I/O ports and Table 15.16 lists I/O ports and pin functions.

Table 15.15 Specifications of I/O Ports (80-pin LQFP)

Item	Description
I/O pins	44
Input pins	13
Number of ports	11 (1 to 4, 6, 7, 9, A, B, D, E)
Open drain outputs	2 (RIIC pin)
Large-current output	6 (MTU3 pin and GPT pin)
Schmitt trigger input pins	All port inputs, CAN inputs, IRQ inputs, MTU3 inputs, POE3 inputs, RIIC inputs, SCI inputs, A/D trigger inputs, NMI inputs, GPT inputs, and LIN inputs
Others	• Each pin is capable of driving a capacitive load of 30 pF in the case of a TTL load. • When configured as an output, a pin is capable of driving a Darlington transistor. • A pin is always capable of reading the status of the pins.

Table 15.16 Port Functions (80-Pin LQFP) (1 / 3)

			Function						
Port	Description	Bit	I/O	Input	Output	CMOS Input	Schmitt Trigger Input	Open Drain Output Capability	Large-Current Output
Port 1	General I/O port pins, MTU3 inputs, and interrupt inputs	0	P10	MTCLKD-B/IRQ0-A		—	All input functions	—	—
		1	P11	MTCLKC-B/IRQ1-A			All input functions		
Port 2	General I/O port pins, MTU3 inputs interrupt inputs, A/D converter inputs, RSPI I/O signal, LIN I/O signal, and CAN I/O signal	0	P20	MTCLKB-B/IRQ7/ ADTRG0#-B		—	All input functions	—	—
		1	P21	MTCLKA-B/IRQ6/ ADTRG1#-B			All input functions		
		2	P22/MISO-A	LRX/CRX-B/ ADTRG#		MISO-A	P22/LRX/ CRX-B/ ADTRG#		
		3	P23/MOSI-A		LTX/CTX-B	MOSI-A	P23		
		4	P24/RSPCK-A			RSPCK-A	P24		
Port 3	General I/O port pins, MTU3 I/O signal, RSPI I/O signal	0	P30/MTIOC0B-B/ SSL0-A	MTCLKD-A		SSL0-A	P30/MTIOC0B-B/MTCLKD-A	—	—
		1	P31/MTIOC0A-B	MTCLKC-A	SSL1-A	—	All input functions		
		2	P32/MTIOC3C	MTCLKB-A	SSL2-A		All input functions		
		3	P33/MTIOC3A	MTCLKA-A	SSL3-A		All input functions		

Table 15.16 Port Functions (80-Pin LQFP) (2 / 3)

Port	Description	Bit	Function			CMOS Input	Schmitt Trigger Input	Open Drain Output Capability	Large-Current Output
			I/O	Input	Output				
Port 4	A/D converter inputs and general input port pins	0		P40/AN000		—	P40	—	—
		1		P41/AN001			P41		
		2		P42/AN002			P42		
		3		P43/AN003/ CVREFL			P43		
		4		P44/AN100			P44		
		5		P45/AN101			P45		
		6		P46/AN102			P46		
		7		P47/AN103/ CVREFH			P47		
Port 6	A/D converter inputs and general input port pins	0		P60/AN0		—	P60	—	—
		1		P61/AN1			P61		
		2		P62/AN2			P62		
		3		P63/AN3			P63		
Port 7	General I/O port pins, POE3 inputs, interrupt inputs, MTU3 I/O signal, and GPT I/O signal	0	P70	POE0#/IRQ5		—	All input functions	—	—
		1	P71/MTIOC3B/ GTIOC0A-A				All input functions		√
		2	P72/MTIOC4A/ GTIOC1A-A				All input functions		√
		3	P73/MTIOC4B/ GTIOC2A-A				All input functions		√
		4	P74/MTIOC3D/ GTIOC0B-A				All input functions		√
		5	P75/MTIOC4C/ GTIOC1B-A				All input functions		√
		6	P76/MTIOC4D/ GTIOC2B-A				All input functions		√
Port 9	General I/O port pins, MTU3 I/O signal, POE3 inputs, and interrupt inputs	1	P91/MTIOC7C			—	All input functions	—	—
		2	P92/MTIOC6D				All input functions		
		3	P93/MTIOC7B				All input functions		
		4	P94/MTIOC7A				All input functions		
		5	P95/MTIOC6B				All input functions		
		6	P96	POE4#/IRQ4			All input functions		
Port A	General I/O port pins, MTU3 I/O signal, RSPI I/O signal, and A/D converter inputs	2	PA2/MTIOC2B		SSL1-B	—	All input functions	—	—
		3	PA3/MTIOC2A/ SSL0-B			SSL0-B	PA3/ MTIOC2A		
		4	PA4/MTIOC1B/ RSPCK-B	ADTRG0#-A		RSPCK-B	PA4/ MTIOC1B/ ADTRG0#-A		
		5	PA5/MTIOC1A/ MISO-B	ADTRG1#-A		MISO-B	PA5/ MTIOC1A/ ADTRG1#-A		

Table 15.16 Port Functions (80-Pin LQFP) (3 / 3)

Port	Description	Bit	Function			CMOS Input	Schmitt Trigger Input	Open Drain Output Capability	Large-Current Output
			I/O	Input	Output				
Port B	General I/O port pins, MTU3 I/O signal, RSPI I/O signal, RIIC I/O signal, SCI I/O signal, GPT inputs, POE3 inputs, interrupt inputs, and CAN I/O signal	0	PB0/MTIOC0D/ MOSI-B			MOSI-B	PB0/ MTIOC0D	—	—
		1	PB1/MTIOC0C/ SCL	RXD0		—	All input functions	√ (SCL only)	—
		2	PB2/MTIOC0B-A/ SDA		TXD0		All input functions	√ (SDA only)	—
		3	PB3/MTIOC0A-A/ SCK0				All input functions	—	—
		4	PB4	GTETRG/ POE8#/IRQ3			All input functions		
		5	PB5		TXD2-A/ CTX-A/		All input functions		
		6	PB6	RXD2-A/CRX-A			All input functions		
		7	PB7/SCK2-A				All input functions		
Port D	General I/O port pins, GPT I/O signal, SCI I/O signal, CAN outputs, and on-chip emulator I/O signal	3	PD3/GTIOC2A-B		TXD1/TDO	—	All input functions	—	—
		4	PD4/GTIOC1B-B/ SCK1	TCK		—	All input functions		
		5	PD5/GTIOC1A-B	RXD1/TDI		—	All input functions		
		6	PD6/GTIOC0B-B	TMS			All input functions		
		7	PD7/GTIOC0A-B	TRST#	CTX-C	—	All input functions		
Port E	General I/O port pins, CAN inputs, POE3 inputs, MTU3 inputs, and interrupt inputs	0	PE0	CRX-C		—	All input functions	—	—
		2		PE2/POE10#-A/ NMI			All input functions		
		3	PE3	MTCLKD-C/ POE11#/IRQ2-A			All input functions		
		4	PE4	MTCLKC-C/ POE10#-B/ IRQ1-B			All input functions		

15.3.2 Register Descriptions

Table 15.17 lists registers of I/O ports, and Table 15.18 lists valid bits in each register

Table 15.17 Registers of I/O Ports (60-Pin LQFP) (1 / 2)

Port Symbol	Register Name	Register Symbol	Value after Reset	Address	Access Size
PORT1	Data direction register	DDR	00h	0008 C001h	8
	Data register	DR	00h	0008 C021h	8
	Port register	PORT	Undefined	0008 C041h	8
	Input buffer control register	ICR	00h	0008 C061h	8
PORT2	Data direction register	DDR	00h	0008 C002h	8
	Data register	DR	00h	0008 C022h	8
	Port register	PORT	Undefined	0008 C042h	8
	Input buffer control register	ICR	00h	0008 C062h	8
PORT3	Data direction register	DDR	00h	0008 C003h	8
	Data register	DR	00h	0008 C023h	8
	Port register	PORT	Undefined	0008 C043h	8
	Input buffer control register	ICR	00h	0008 C063h	8
PORT4	Port register	PORT	Undefined	0008 C044h	8
	Input buffer control register	ICR	00h	0008 C064h	8
PORT6	Port register	PORT	Undefined	0008 C046h	8
	Input buffer control register	ICR	00h	0008 C066h	8
PORT7	Data direction register	DDR	00h	0008 C007h	8
	Data register	DR	00h	0008 C027h	8
	Port register	PORT	Undefined	0008 C047h	8
	Input buffer control register	ICR	00h	0008 C067h	8
PORT9	Data direction register	DDR	00h	0008 C009h	8
	Data register	DR	00h	0008 C029h	8
	Port register	PORT	Undefined	0008 C049h	8
	Input buffer control register	ICR	00h	0008 C069h	8
PORTA	Data direction register	DDR	00h	0008 C00Ah	8
	Data register	DR	00h	0008 C02Ah	8
	Port register	PORT	Undefined	0008 C04Ah	8
	Input buffer control register	ICR	00h	0008 C06Ah	8
PORTB	Data direction register	DDR	00h	0008 C00Bh	8
	Data register	DR	00h	0008 C02Bh	8
	Port register	PORT	Undefined	0008 C04Bh	8
	Input buffer control register	ICR	00h	0008 C06Bh	8
PORTD	Data direction register	DDR	00h	0008 C00Dh	8
	Data register	DR	00h	0008 C02Dh	8
	Port register	PORT	Undefined	0008 C04Dh	8
	Input buffer control register	ICR	00h	0008 C06Dh	8
PORTE	Data direction register	DDR	00h	0008 C00Eh	8
	Data register	DR	00h	0008 C02Eh	8
	Port register	PORT	Undefined	0008 C04Eh	8
	Input buffer control register	ICR	00h	0008 C06Eh	8

Table 15.17 Registers of I/O Ports (60-Pin LQFP) (2 / 2)

Port Symbol	Register Name	Register Symbol	Value after Reset	Address	Access Size
IOPORT	Port function register 8	PF8IRQ	00h	0008 C108h	8
	Port function register A	PFAADC	00h	0008 C10Ah	8
	Port function register C	PFCMTU	00h	0008 C10Ch	8
	Port function register D	PFDGPT	00h	0008 C10Dh	8
	Port function register G	PFGSPI	00h	0008 C110h	8
	Port function register H	PFHSPI	00h	0008 C111h	8
	Port function register J	PFJCAN	00h	0008 C113h	8
	Port function register K	PFKLIN	00h	0008 C114h	8
	Port function register M	PFMPOE	00h	0008 C116h	8
	Port function register N	PFNPOE	00h	0008 C117h	8

Table 15.18 Valid Bits in Each Register (80-Pin LQFP) (1 / 2)

Register Symbol	b7	b6	b5	b4	b3	b2	b1	b0
PORT1.DDR	×	×	×	×	×	×	√	√
PORT2.DDR	×	×	×	√	√	√	√	√
PORT3.DDR	×	×	×	×	√	√	√	√
PORT7.DDR	×	√	√	√	√	√	√	√
PORT9.DDR	×	√	√	√	√	√	√	×
PORTA.DDR	×	×	√	√	√	√	×	×
PORTB.DDR	√	√	√	√	√	√	√	√
PORTD.DDR	√	√	√	√	√	×	×	×
PORTE.DDR	×	×	×	√	√	×	×	√
PORT1.DR	×	×	×	×	×	×	√	√
PORT2.DR	×	×	×	√	√	√	√	√
PORT3.DR	×	×	×	×	√	√	√	√
PORT7.DR	×	√	√	√	√	√	√	√
PORT9.DR	×	√	√	√	√	√	√	×
PORTA.DR	×	×	√	√	√	√	×	×
PORTB.DR	√	√	√	√	√	√	√	√
PORTD.DR	√	√	√	√	√	×	×	×
PORTE.DR	×	×	×	√	√	×	×	√
PORT1.PORT	×	×	×	×	×	×	√	√
PORT2.PORT	×	×	×	√	√	√	√	√
PORT3.PORT	×	×	×	×	√	√	√	√
PORT4.PORT	√	√	√	√	√	√	√	√
PORT6.PORT	×	×	×	×	√	√	√	√
PORT7.PORT	×	√	√	√	√	√	√	√
PORT9.PORT	×	√	√	√	√	√	√	×
PORTA.PORT	×	×	√	√	√	√	×	×
PORTB.PORT	√	√	√	√	√	√	√	√
PORTD.PORT	√	√	√	√	√	×	×	×
PORTE.PORT	×	×	×	√	√	√	×	√
PORT1.ICR	×	×	×	×	×	×	√	√
PORT2.ICR	×	×	×	√	√	√	√	√
PORT3.ICR	×	×	×	×	√	√	√	√
PORT4.ICR	√	√	√	√	√	√	√	√
PORT6.ICR	×	×	×	×	√	√	√	√
PORT7.ICR	×	√	√	√	√	√	√	√
PORT9.ICR	×	√	√	√	√	√	√	×
PORTA.ICR	×	×	√	√	√	√	×	×
PORTB.ICR	√	√	√	√	√	√	√	√
PORTD.ICR	√	√	√	√	√	×	×	×
PORTE.ICR	×	×	×	√	√	×	×	√
IOPORT.PF8IRQ	×	×	×	×	√	√	√	√
IOPORT.PFAADC	×	×	×	×	×	×	√	√
IOPORT.PFCMTU	√	√	×	×	×	×	√	√
IOPORT.PFDGPT	×	×	×	×	×	×	×	√

Table 15.18 Valid Bits in Each Register (80-Pin LQFP) (2 / 2)

Register Symbol	b7	b6	b5	b4	b3	b2	b1	b0
IOPORT.PFGSPI	√	√	√	√	√	√	√	×
IOPORT.PFHSPI	×	×	×	×	×	×	√	√
IOPORT.PFJCAN	√	√	×	×	×	×	×	√
IOPORT.PFKLIN	×	×	×	×	×	×	×	√
IOPORT.PFMPOE	×	×	×	√	√	√	√	√
IOPORT.PFNPOE	√	×	×	×	×	×	×	×

√: Enabled bit, x: Disabled bit (Reserved)

15.3.2.1 Data Direction Register (DDR)

Address: PORT1.DDR 0008 C001h, PORT2.DDR 0008 C002h, PORT3.DDR 0008 C003h, PORT7.DDR 0008 C007h, PORT9.DDR 0008 C009h, PORTA.DDR 0008 C00Ah, PORTB.DDR 0008 C00Bh, PORTD.DDR 0008 C00Dh, PORTE.DDR 0008 C00Eh

	b7	b6	b5	b4	b3	b2	b1	b0
	B7	B6	B5	B4	B3	B2	B1	B0
Value after reset:	0	0	0	0	0	0	0	0

Notes:

1. The lower two bits are valid and the upper six bits are reserved in PORT1.DDR.
   The lower five bits are valid and the upper three bits are reserved in PORT2.DDR.
   The lower four bits are valid and the upper four bits are reserved in PORT3.DDR.
   The lower seven bits are valid and the highest order bit is reserved in PORT7.DDR.
   Bit 6 to bit 1 are valid and bit 7 and bit 0 are reserved in PORT9.DDR.
   Bit 5 to bit 2 are valid and bit 7, bit 6, bit 1, and bit 0 are reserved in PORTA.DDR.
   The upper five bits are valid and the lower three bits are reserved in PORTD.DDR.
   Bit 4, bit 3, bit 0 are valid and bit 7 to bit 5, bit 2, bit 1 are reserved in PORTE.DDR.
2. The reserved bits are read as 0. The write value should always be 0.

Bit	Symbol	Bit Name	Description	R/W
b0	B0	Pn0 I/O Select (n=1 to 3, 7, 9, A, B, D, E)	0: An input pin 1: An output pin	R/W
b1	B1	Pn1 I/O Select		R/W
b2	B2	Pn2 I/O Select		R/W
b3	B3	Pn3 I/O Select		R/W
b4	B4	Pn4 I/O Select		R/W
b5	B5	Pn5 I/O Select		R/W
b6	B6	Pn6 I/O Select		R/W
b7	B7	Pn7 I/O Select		R/W

n = 1 to 3, 7, 9, A, B, D, E

Each PORTn.DDR is used to select the input or output direction for individual pins of the corresponding port that have been configured to function as general I/O pins.
Each bit of a PORTn.DDR (n = 1 to 3, 7, 9, A, B, D, E) corresponds to a pin of Pn, and the settings can change from bit to bit.

15.3.2.2 Data Register (DR)

Address: PORT1.DR 0008 C021h, PORT2.DR 0008 C022h, PORT3.DR 0008 C023h, PORT7.DR 0008 C027h, PORT9.DR 0008 C029h, PORTA.DR 0008 C02Ah, PORTB.DR 0008 C02Bh, PORTD.DR 0008 C02Dh, PORTE.DR 0008 C02Eh

	b7	b6	b5	b4	b3	b2	b1	b0
	B7	B6	B5	B4	B3	B2	B1	B0
Value after reset:	0	0	0	0	0	0	0	0

Notes:

1. The lower two bits are valid and the upper six bits are reserved in PORT1.DR.
   The lower five bits are valid and the upper three bits are reserved in PORT2.DR.
   The lower four bits are valid and the upper four bits are reserved in PORT3.DR.
   The lower seven bits are valid and the highest order bit is reserved in PORT7.DR.
   Bit 6 to bit 1 are valid and bit 7 and bit 0 are reserved in PORT9.DR.
   Bit 5 to bit 2 are valid and bit 7, bit 6, bit 1, and bit 0 are reserved in PORTA.DR.
   The upper five bits are valid and the lower three bits are reserved in PORTD.DR.
   Bit 4, bit 3, bit 0 are valid and bit 7 to bit 5, bit 2, bit 1 are reserved in PORTE.DR.
2. The reserved bits are read as 0. The write value should always be 0.

Bit	Symbol	Bit Name	Description	R/W
b0	B0	Pn0 Output Data Store (n=1 to 3, 7, 9, A, B, D, E)	Output data are stored.	R/W
b1	B1	Pn1 Output Data Store		R/W
b2	B2	Pn2 Output Data Store		R/W
b3	B3	Pn3 Output Data Store		R/W
b4	B4	Pn4 Output Data Store		R/W
b5	B5	Pn5 Output Data Store		R/W
b6	B6	Pn6 Output Data Store		R/W
b7	B7	Pn7 Output Data Store		R/W

n = 1 to 3, 7, 9, A, B, D, E

Each PORTn.DR (n = to 3, 7, 9, A, B, D, E) stores the output data from the individual pins of the corresponding port used as a general I/O port.

15.3.2.3 Port Register (PORT)

Address: PORT1.PORT 0008 C041h, PORT2.PORT 0008 C042h, PORT3.PORT 0008 C043h, PORT4.PORT 0008 C044h, PORT6.PORT 0008 C046h, PORT7.PORT 0008 C047h, PORT9.PORT 0008 C049h, PORTA.PORT 0008 C04Ah, PORTB.PORT 0008 C04Bh, PORTD.PORT 0008 C04Dh, PORTE.PORT 0008 C04Eh

	b7	b6	b5	b4	b3	b2	b1	b0
	B7	B6	B5	B4	B3	B2	B1	B0
Value after reset:	x	x	x	x	x	x	x	x

Notes:

1. The lower two bits are valid and the upper six bits are reserved in PORT1.PORT.
   The lower five bits are valid and the upper three bits are reserved in PORT2.PORT.
   The lower four bits are valid and the upper four bits are reserved in PORT3.PORT.
   The lower four bits are valid and the upper four bits are reserved in PORT6.PORT.
   The lower seven bits are valid and the highest order bit is reserved in PORT7.PORT.
   Bit 6 to bit 1 are valid and bit 7 and bit 0 are reserved in PORT9.PORT.
   Bit 5 to bit 2 are valid and bit 7, bit 6, bit 1, bit 0 are reserved in PORTA.PORT.
   The upper five bits are valid and the lower three bits are reserved in PORTD.PORT.
   Bit 4 to bit 2, bit 0 are valid and bit 7 to bit 5, and bit 1 are reserved in PORTE.PORT.
2. The reserved bits are read as 1. Writing to these bits has no effect.

Bit	Symbol	Bit Name	Description	R/W
b0	B0	Pn0 (n=1 to 4, 6, 7, 9, A, B, D, E)	Individual pin states of the corresponding port are reflected.	R
b1	B1	Pn1		R
b2	B2	Pn2		R
b3	B3	Pn3		R
b4	B4	Pn4		R
b5	B5	Pn5		R
b6	B6	Pn6		R
b7	B7	Pn7		R

n = 1 to 4, 6, 7, 9, A, B, D, E

PORT reflects individual pin states of the corresponding port.

When a PORTn.PORT (n = 1 to 4, 6, 7, 9, A, B, D, E) is read, the corresponding pin states are read out to here.

15.3.2.4 Input Buffer Control Register (ICR)

Address: PORT1.ICR 0008 C061h, PORT2.ICR 0008 C062h, PORT3.ICR 0008 C063h, PORT4.ICR 0008 C064h, PORT6.ICR 0008 C066h, PORT7.ICR 0008 C067h, PORT9.ICR 0008 C069h, PORTA.ICR 0008 C06Ah, PORTB.ICR 0008 C06Bh, PORTD.ICR 0008 C06Dh, PORTE.ICR 0008 C06Eh

	b7	b6	b5	b4	b3	b2	b1	b0
	B7	B6	B5	B4	B3	B2	B1	B0
Value after reset:	0	0	0	0	0	0	0	0

Notes:
1. The lower two bits are valid and the upper six bits are reserved in PORT1.ICR.
   The lower five bits are valid and the upper three bits are reserved in PORT2.ICR.
   The lower four bits are valid and the upper four bits are reserved in PORT3.ICR.
   The lower four bits are valid and the upper four bits are reserved in PORT6.ICR.
   The lower seven bits are valid and the highest order bit is reserved in PORT7.ICR.
   Bit 6 to bit 1 are valid, and bit 7 and bit 0 are reserved in PORT9.ICR.
   Bit 5 to bit 2 are valid and bit 7, bit 6, bit 1, and bit 0 are reserved in PORTA.ICR.
   The upper five bits are valid and the lower three bits are reserved in PORTD.ICR.
   Bit 4, bit 3, and bit 0 are valid and bit 7 to bit 5, bit 2, and bit 1 are reserved in PORTE.ICR.
2. The reserved bits are read as 0. The write value should always be 0.

Bit	Symbol	Bit Name	Description	R/W
b0	B0*1	Pn0 Input Buffer Control (n=1 to 4, 6, 7, 9, A, B, D, E)	0: The input buffer for the corresponding pin is disabled. 1: The input buffer for the corresponding pin is enabled.	R/W
b1	B1*1	Pn1 Input Buffer Control		R/W
b2	B2*1	Pn2 Input Buffer Control		R/W
b3	B3*1	Pn3 Input Buffer Control		R/W
b4	B4*1	Pn4 Input Buffer Control		R/W
b5	B5*1	Pn5 Input Buffer Control		R/W
b6	B6*1	Pn6 Input Buffer Control		R/W
b7	B7*1	Pn7 Input Buffer Control		R/W

n = 1 to 4, 6, 7, 9, A, B, D, E

Note 1. For pins being used as input pins for peripheral modules, set the corresponding bits to 1. Set the bits corresponding to pins that are not being used for their input functions or are being used as analog input pins to 0.

Each PORTn.ICR controls the input buffers for the individual pins of the corresponding port.

Each bit of a PORTn.ICR (1 to 4, 6, 7, 9, A, B, D, E) corresponds to a pin of PORTn, and the settings can change from bit to bit.

When to be used as an input pin for the peripheral module, the input buffer for the corresponding pin should be enabled beforehand by setting the PORTn.ICR bit to 1. If this register is used as an input pin for the peripheral module while the PORTn.ICR bit is 0, the input signal to the peripheral module is fixed high.

When a PORTn.ICR register is read, the pin states of the corresponding port are read out regardless of the values in PORTn.ICR. For bits where the value in PORTn.ICR is 0, however, the value may not reflect the pin state on the corresponding peripheral module side.

Changes in the settings of a PORTn.ICR may generate edges internally, depending on the pin state. For this reason, change the settings of PORTn.ICR while the corresponding input pins are not in use. For example, in the case of IRQi (i = 0 to 7) inputs, change settings of the corresponding PORTn.ICR with interrupts disabled by clearing the IR flag in IRi (i = 64 to 71 ("i" shows an interrupt vector number of the IRQ)) of the interrupt controller (ICU) to 0, and then enable the corresponding interrupts. If a change to a PORTn.ICR setting does generate an edge, negate the edge.

15.3.2.5 Port Function Register 8 (PF8IRQ)

Address: 0008 C108h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	ITS1[1:0]		—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1 to b0	—	Reserved	These bits are always read as 0. The write value should always be 0.	R
b3-b2	ITS1[1:0]	IRQ1 P in Select	b3 b2 0 0: P11 is designated as the IRQ1-A input pin. 0 1: PE4 is designated as the IRQ1-B input pin. 1 0: Reserved 1 1: Reserved	R
b7-b4	—	Reserved	These bits are always read as 0. The write value should always be 0.	R

PF8IRQ is used to select pins for IRQ1 input.

ITS1 Bit (IRQ1 Pin Select)

This bit selects a pin for an IRQ1 input.

15.3.2.6 Port Function Register A (PFAADC)

Address: 0008 C10Ah

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	ADTRG1S	ADTRG0S
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	ADTRG0S	ADTRG0# Input Select	0:PA4 is designated as the ADTRG0#-A input pin. 1:P20 is designated as the ADTRG0#-B input pin.	R/W
b1	ADTRG1S	ADTRG1# Input Select	0:PA5 is designated as the ADTRG1#-A input pin. 1:P21 is designated as the ADTRG1#-B input pin.	R/W
b7 to b2	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

PFAADC is used to select the ADTRG0# and ADTRG1# pins.

ADTRGnS Bit (ADTRGn# Input Select) (n=0 and 1)

This bit selects a pin for an ADTRGn# input.

15.3.2.7 Port Function Register C (PFCMTU)

Address: 0008 C10Ch

	b7	b6	b5	b4	b3	b2	b1	b0
	TCLKS[1:0]		—	—	—	—	MTUS1	MTUS0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Bit Name	R/W
b0	MTUS0	MTU3 Pin Select 0	0:PB3 is designated as the MTIOC0A-A pin. 1:P31 is designated as the MTIOC0A-B pin.	R/W
b1	MTUS1	MTU3 Pin Select 1	0:PB2 is designated as the MTIOC0B-A pin. 1:P30 is designated as the MTIOC0B-B pin.	R/W
b5 to b2	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7 to b6	TCLKS[1:0]	MTCLK Pin Select	b7 b6 0 0:P33 is designated as the MTCLKA-A pin. P32 is designated as the MTCLKB-A pin. P31 is designated as the MTCLKC-A pin. P30 is designated as the MTCLKD-A pin. 0 1:P21 is designated as the MTCLKA-B pin. P20 is designated as the MTCLKB-B pin. P11 is designated as the MTCLKC-B pin. P10 is designated as the MTCLKD-B pin. 1 0:PE4 is designated as the MTCLKC-C pin. PE3 is designated as the MTCLKD-C pin. (MTCLKA pin and MTCLKB pins cannot be selected.) 1 1:Setting prohibited	R/W

PFCMTU is used to select pins for MTU3.

MTUSi Bit (MTU3 Pin Select) (i = 0 and 1)

Each bit selects a pin for an MTU3 input/output.

TCLKS[1:0] Bit (MTCLK Pin Select)

This bit selects a pin for a MTCLK input of the MTU3.

15.3.2.8 Port Function Register D (PFDGPT)

Address: 0008 C10Dh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	GPTS
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	GPTS	GPT Pin Select	0:P71 is designated as the GTIOC0A-A pin. P74 is designated as the GTIOC0B-A pin. P72 is designated as the GTIOC1A-A pin. P75 is designated as the GTIOC1B -A pin. P73 is designated as the GTIOC2A-A pin. P76 is designated as the GTIOC2B-A pin. 1:PD7 is designated as the GTIOC0A-B pin. PD6 is designated as the GTIOC0B-B pin. PD5 is designated as the GTIOC1A-B pin. PD4 is designated as the GTIOC1B-B pin. PD3 is designated as the GTIOC2A-B pin. Note that the GTIOC2B-B pin is not selectable.	R/W
b7 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

PFDGPT is used to select a pin for GPT.

GPTS Bit (GPT I/O Pin Select)

Each bit selects a pin for a GPT input/output.

15.3.2.9 Port Function Register G (PFGSPI)

Address: 0008 C110h

	b7	b6	b5	b4	b3	b2	b1	b0
	SSL3E	SSL2E	SSL1E	SSL0E	MISOE	MOSIE	RSPCKE	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b1	RSPCKE	RSPCK Output Enable	0:RSPCK pin is disabled. 1:RSPCK pin is enabled.	R/W
b2	MOSIE	MOSI Output Enable	0:MOSI pin is disabled. 1:MOSI pin is enabled.	R/W
b3	MISOE	MISO Output Enable	0:MISO pin is disabled. 1:MISO pin is enabled.	R/W
b4	SSL0E	SSL0 Output Enable	0:SSL0 pin is disabled. 1:SSL0 pin is enabled.	R/W
b5	SSL1E	SSL1 Output Enable	0:SSL1 pin is disabled. 1:SSL1 pin is enabled.	R/W
b6	SSL2E	SSL2 Output Enable	0:SSL2 pin is disabled. 1:SSL2 pin is enabled.	R/W
b7	SSL3E	SSL3 Output Enable	0:SSL3 pin is disabled. 1:SSL3 pin is enabled.	R/W

PFGSPI is used to select I/O pins for the RSPI.

RSPCKE Bit (RSPCK Output Enable)

This bit enables or disables the RSPCK pin. Set this bit to 1 to use the RSPCK pin.

MOSIE Bit (MOSI Output Enable)

This bit enables or disables the MOSI pin. Set this bit to 1 to use the MOSI pin.

MISOE Bit (MISO Output Enable)

This bit enables or disables the MISO pin. Set this bit to 1 to use the MISO pin.

SSL0E Bit (SSL0 Output Enable)

This bit enables or disables the SSL0 pin. Set this bit to 1 to use the SSL0 pin.

SSL1E Bit (SSL1 Output Enable)

This bit enables or disables the SSL1 pin. Set this bit to 1 to use the SSL1 pin.

SSL2E Bit (SSL2 Output Enable)

This bit enables or disables the SSL2 pin. Set this bit to 1 to use the SSL2 pin.

SSL3E Bit (SSL3 Output Enable)

This bit enables or disables the SSL3 pin. Set this bit to 1 to use the SSL3 pin.

15.3.2.10 Port Function Register H (PFHSPI)

Address: 0008 C111h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	RSPIS[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1 to b0	RSPIS[1:0]	RSPI Pin Select	b1 b0 0 0:P22 is designated as the MISO-A pin. P23 is designated as the MOSI-A pin. P24 is designated as the RSPCK-A pin. P30 is designated as the SSL0-A pin. P31 is designated as the SSL1-A pin. P32 is designated as the SSL2-A pin. P33 is designated as the SSL3-A pin. 0 1:PA5 is designated as the MISO-B pin. PB0 is designated as the MOSI-B pin. PA4 is designated as the RSPCK-B pin. PA3 is designated as the SSL0-B pin. PA2 is designated as the SSL1-B pin. (SSL2 pin and SSL3 pins cannot be selected.) 1 0:Setting prohibited 1 1:Setting prohibited	R/W
b2 to b7	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

PFHSPI is used to select I/O pins for the RSPI.

RSPIS[1:0] Bit (RSPI Pin Select)

This bit selects a pin for an RSPI input/output.

As an enable bit is provided for each RSPI input/output pin, the input/output pin is selectable while the corresponding enable bit is 1. Otherwise, the pin cannot be selected.

15.3.2.11 Port Function Register J (PFJCAN)

Address: 0008 C113h

	b7	b6	b5	b4	b3	b2	b1	b0
	CANS[1:0]		—	—	—	—	—	CANE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	CANE	CAN Pin Enable	0:The CTX and CRX pins are disabled. 1:The CTX and CRX pins are enabled.	R/W
b5 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7 to b6	CANS[1:0]	CAN Pin Select	b7 b6 0 0:PB5 is designated as the CTX-A pin. PB6 is designated as the CRX-A pin. 0 1:P23 is designated as the CTX-B pin. P22 is designated as the CRX-B pin. 1 0:PE0 is designated as the CRX-C pin. PD7 is designated as the CTX-C pin. 1 1:Setting prohibited	R/W

PFJCAN is used to select I/O pins for the CAN.

CANE Bit (CAN Pin Enable)

This bit enables or disables the CAN pin. Set this bit to 1 to use the CAN pin.

CANS[1:0] Bit (CAN Pin Select)

These bits select I/O pins for the CAN.

15.3.2.12 Port Function Register K (PFKLIN)

Address: 0008 C114h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	LINE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	LINE	LIN Pin Enable	0:LTX and LRX pins are disabled. 1:LTX and LRX pins are enabled.	R/W
b7 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

PFKLIN is used to select I/O pins for the LIN.

LINE Bit (LIN Pin Enable)

This bit enables or disables the LIN pin. Set this bit to 1 to use the LIN pin.

15.3.2.13 Port Function Register M (PFMPOE)

Address: 0008 C116h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	POE11E	POE10E	POE8E	POE4E	POE0E
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	POE0E	POE0# Input Enable	0:Designated as an I/O port pin 1:Designated as the POEn# input pin (n = 0, 4, 8, 10, 11)	R/W*1
b1	POE4E	POE4# Input Enable		R/W*1
b2	POE8E	POE8# Input Enable		R/W*1
b3	POE10E	POE10# Input Enable		R/W*1
b4	POE11E	POE11# Input Enable		R/W*1
b7 to b5	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

Note 1. The first round of writing after a reset is enabled; though subsequent writing is not allowed.

PFMPOE enables or disables POEn# input pins.
To prevent the error in the system, be sure to write to this register after a reset.
The first round of writing after a reset is only enabled.

POEnE Bit (POEn# Input Enable) (n = 0, 4, 8, 10, 11)

Each bit enables or disables the corresponding POEn# input.
To use POEn#, set the corresponding POEnE bit to 1.

15.3.2.14 Port Function Register N (PFNPOE)

Address: 0008 C117h

	b7	b6	b5	b4	b3	b2	b1	b0
	POE10S	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b6-b0	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7	POE10S	POE10#	0:PE2 is designated as the POE10#-A input pin. 1:PE4 is designated as the POE10#-B input pin.	R/W *1

Note 1. The first round of writing after a reset is enabled; though subsequent writing is not allowed.

PFNPOE enables or disables POEn# input pins.
To prevent the error in the system, be sure to write to this register after a reset.
The first round of writing after a reset is only enabled.

POE10S Bit (POE10# Input Select)

This bit select input pins for the POE10#.

15.3.3 Settings of Ports

When individual pins for peripheral modules are enabled, the settings for each port are modified.
An input pin for the peripheral module is specified independently by the peripheral module. To use an input pin for the peripheral module, the corresponding bit in the input buffer control register (PORTn.ICR) should be set to 1 to enable the input buffer, except for the port register read, NMI, and POEn# pin inputs.
The pins that function as output pins and I/O pins should be enabled for respective peripheral modules. If a conflict occurs among the output signal enable settings for peripheral modules, that are multiplexed to the same port, the priority will be handled according to the port-multiplexed priority.
Table 15.19 lists the port-multiplexed priority for peripheral modules.

Table 15.19 Port-Multiplexed Priority for Peripheral Modules (80-Pin LQFP)

Priority		Module Name	Output Pins
High	1	RSPI	RSPCK, MOSI, MISO, SSL0 to SSL3
↑	2	CAN	CTX
	3	LIN	LTX
	4	MTU0 to MTU7	MTIOC0A, MTIOC0B, MTIOC0C, MTIOC0D, MTIOC1A, MTIOC1B, MTIOC2A, MTIOC2B, MTIOC3A, MTIOC3B, MTIOC3C, MTIOC3D, MTIOC4A, MTIOC4B, MTIOC4C, MTIOC4D, MTIOC6B, MTIOC6D, MTIOC7A, MTIOC7B, MTIOC7C
	5	GPT0 to GPT3	GTIOC0A, GTIOC0B, GTIOC1A, GTIOC1B, GTIOC2A, GTIOC2B
	6	SCI0 to SCI2	SCK0 to SCK2, TXD0 to TXD2
	7	RIIC	SCL, SDA
Low	8	IOPORT	P10 to P11, P20 to P24, P30 to P33, P70 to P76, P91 to P96, PA2 to PA5, PB0 to PB7, PD3 to PD7, PE0, PE3 to PE4

15.3.4 List of Output Enable Settings

Table 15.20 lists the output enable settings for each port.
For details on the applicable output signals, see descriptions of the registers for each peripheral module.
Setting the port function register changes the functions of peripheral-module pins with names ending in A to C.

Table 15.20 Output Enable Settings for Each Port (80-pin LQFP) (1 / 4)

Port	Module Name	Output Signal Name	Port Function Register Settings	Peripheral Module Settings
P10	PORT1	P10		PORT1.DDR.B0 = 1
P11	PORT1	P11		PORT1.DDR.B1 = 1
P20	PORT2	P20		PORT2.DDR.B0 = 1
P21	PORT2	P21		PORT2.DDR.B1 = 1
P22	RSPI	MISO-A	PFGSPI.MISOE = 1 PFHSPI.RSPIS[1:0] = 00	(In addition to the pin enable setting, input/output switching function for the peripheral module is provided.)
	PORT2	P22		PORT2.DDR.B2 = 1
P23	RSPI	MOSI-A	PFGSPI.MOSIE = 1 PFHSPI.RSPIS[1:0] = 00	(In addition to the pin enable setting, input/output switching function for the peripheral module is provided.)
	CAN	CTX-B	PFJCAN.CANE =1 PFJCAN.CANS[1:0] = 01	(The signal output state is specified by the peripheral module settings.)
	LIN	LTX	PFKLIN.LINE = 1	(The signal output state is specified by the peripheral module settings.)
	PORT2	P23		PORT2.DDR.B3 =1
P24	RSPI	RSPCK-A	PFGSPI.RSPCKE =1 PFHSPI.RSPIS[1:0] = 00	(In addition to the pin enable setting, input/output switching function for the peripheral module is provided.)
	PORT2	P24		PORT2.DDR.B4 = 1
P30	RSPI	SSL0-A	PFGSPI.SSL0E = 1 PFHSPI.RSPIS[1:0] = 00	(In addition to the pin enable setting, input/output switching function for the peripheral module is provided.)
	MTU0	MTIOC0B-B	PFCMTU.MTUS1 = 1	(The signal output state is specified by the peripheral module settings.)
	PORT3	P30		PORT3.DDR.B0 = 1
P31	RSPI	SSL1-A	PFGSPI.SSL1E = 1 PFHSPI.RSPIS[1:0] = 00	(The signal output state is specified by the peripheral module settings.)
	MTU0	MTIOC0A-B	PFCMTU.MTUS0 = 1	(The signal output state is specified by the peripheral module settings.)
	PORT3	P31		PORT3.DDR.B1 = 1
P32	RSPI	SSL2-A	PFGSPI.SSL2E = 1 PFHSPI.RSPIS[1:0] = 00	(The signal output state is specified by the peripheral module settings.)
	MTU3	MTIOC3C		(The signal output state is specified by the peripheral module settings.)
	PORT3	P32		PORT3.DDR.B2 = 1
P33	RSPI	SSL3-A	PFGSPI.SSL3E = 1 PFHSPI.RSPIS[1:0] = 00	(The signal output state is specified by the peripheral module settings.)
	MTU3	MTIOC3A		(The signal output state is specified by the peripheral module settings.)
	PORT3	P33		PORT3.DDR.B3 = 1
P70	PORT7	P70		PORT7.DDR.B0 = 1
P71	MTU3	MTIOC3B		(The signal output state is specified by the peripheral module settings.)
	GPT0	GTIOC0A-A	PFDGPT.GPTS = 0	(The signal output state is specified by the peripheral module settings.)
	PORT7	P71		PORT7.DDR.B1 = 1

Table 15.20 Output Enable Settings for Each Port (80-pin LQFP) (2 / 4)

Port	Module Name	Output Signal Name	Port Function Register Settings	Peripheral Module Settings
P72	MTU4	MTIOC4A		(The signal output state is specified by the peripheral module settings.)
	GPT1	GTIOC1A-A	PFDGPT.GPTS = 0	(The signal output state is specified by the peripheral module settings.)
	PORT7	P72		PORT7.DDR.B2 = 1
P73	MTU4	MTIOC4B		(The signal output state is specified by the peripheral module settings.)
	GPT2	GTIOC2A-A	PFDGPT.GPTS = 0	(The signal output state is specified by the peripheral module settings.)
	PORT7	P73		PORT7.DDR.B3 = 1
P74	MTU3	MTIOC3D		(The signal output state is specified by the peripheral module settings.)
	GPT0	GTIOC0B-A	PFDGPT.GPTS = 0	(The signal output state is specified by the peripheral module settings.)
	PORT7	P74		PORT7.DDR.B4 = 1
P75	MTU4	MTIOC4C		(The signal output state is specified by the peripheral module settings.)
	GPT1	GTIOC1B-A	PFDGPT.GPTS = 0	(The signal output state is specified by the peripheral module settings.)
	PORT7	P75		PORT7.DDR.B5 = 1
P76	MTU4	MTIOC4D		(The signal output state is specified by the peripheral module settings.)
	GPT2	GTIOC2B-A	PFDGPT.GPTS = 0	(The signal output state is specified by the peripheral module settings.)
	PORT7	P76		PORT7.DDR.B6 = 1
P91	MTU7	MTIOC7C		(The signal output state is specified by the peripheral module settings.)
	PORT9	P91		PORT9.DDR.B1 = 1
P92	MTU6	MTIOC6D		(The signal output state is specified by the peripheral module settings.)
	PORT9	P92		PORT9.DDR.B2 = 1
P93	MTU7	MTIOC7B		(The signal output state is specified by the peripheral module settings.)
	PORT9	P93		PORT9.DDR.B3 = 1
P94	MTU7	MTIOC7A		(The signal output state is specified by the peripheral module settings.)
	PORT9	P94		PORT9.DDR.B4 = 1
P95	MTU6	MTIOC6B		(The signal output state is specified by the peripheral module settings.)
	PORT9	P95		PORT9.DDR.B5 = 1
P96	PORT9	P96		PORT9.DDR.B6 = 1
PA2	RSPI	SSL1-B	PFGSPI.SSL1E = 1 PFHSPI.RSPIS[1:0] = 01	(The signal output state is specified by the peripheral module settings.)
	MTU2	MTIOC2B		(The signal output state is specified by the peripheral module settings.)
	PORTA	PA2		PORTA.DDR.B2 = 1
PA3	RSPI	SSL0-B	PFGSPI.SSL0E = 1 PFHSPI.RSPIS[1:0] = 01	(In addition to the pin enable setting, input/output switching function for the peripheral module is provided.)
	MTU2	MTIOC2A		(The signal output state is specified by the peripheral module settings.)
	PORTA	PA3		PORTA.DDR.B3 = 1

Table 15.20 Output Enable Settings for Each Port (80-pin LQFP) (3 / 4)

Port	Module Name	Output Signal Name	Port Function Register Settings	Peripheral Module Settings
PA4	RSPI	RSPCK-B	PFGSPI.RSPCKE = 1 PFHSPI.RSPIS[1:0] = 01	(In addition to the pin enable setting, input/output switching function for the peripheral module is provided.)
	MTU1	MTIOC1B		(The signal output state is specified by the peripheral module settings.)
	PORTA	PA4		PORTA.DDR.B4 = 1
PA5	RSPI	MISO-B	PFGSPI.MISOE = 1 PFHSPI.RSPIS[1:0] = 01	(In addition to the pin enable setting, input/output switching function for the peripheral module is provided.)
	MTU1	MTIOC1A		(The signal output state is specified by the peripheral module settings.)
	PORTA	PA5		PORTA.DDR.B5 = 1
PB0	RSPI	MOSI-B	PFGSPI.MOSIE = 1 PFHSPI.RSPIS[1:0] = 01	(In addition to the pin enable setting, input/output switching function for the peripheral module is provided.)
	MTU0	MTIOC0D		(The signal output state is specified by the peripheral module settings.)
	PORTB	PB0		PORTB.DDR.B0 = 1
PB1	MTU0	MTIOC0C		(The signal output state is specified by the peripheral module settings.)
	RIIC	SCL		RIIC.ICCR1.ICE = 1
	PORTB	PB1		PORTB.DDR.B1 = 1
PB2	MTU0	MTIOC0B-A	PFCMTU.MTUS1 = 0	(The signal output state is specified by the peripheral module settings.)
	SCI0	TXD0		SCI0.SCR.TE = 1
	RIIC	SDA		RIIC.ICCR1.ICE = 1
	PORTB	PB2		PORTB.DDR.B2 = 1
PB3	MTU0	MTIOC0A-A	PFCMTU.MTUS0 = 0	(The signal output state is specified by the peripheral module settings.)
	SCI0	SCK0		When SCI0.SCMR.SMIF = 1: While SMR.GM = 0, SCR.CKE[1:0] = 01 or SMR.GM = 1, SCR.TE = 1 or SCR.RE = 1 When SCI0.SCMR.SMIF = 0: While SMR.CM = 0, SCR.CKE[1:0] = 01 or SMR.CM = 1, SCR.CKE[1] = 0, SCR.TE = 1 or SCR.RE = 1
	PORTB	PB3		PORTB.DDR.B3 = 1
PB4	PORTB	PB4		PORTB.DDR.B4 = 1
PB5	CAN	CTX-A	PFJCAN.CANE = 1 PFJCAN.CANS[1:0] = 00	(The signal output state is specified by the peripheral module settings.)
	SCI2	TXD2-A	PFFSCI.SCI2S = 0	SCI2.SCR.TE = 1
	PORTB	PB5		PORTB.DDR.B5 = 1
PB6	PORTB	PB6		PORTB.DDR.B6 = 1
PB7	SCI2	SCK2-A	PFFSCI.SCI2S = 0	When SCI2.SCMR.SMIF =1: While SMR.GM = 0, SCR.CKE[1:0] = 01 or SMR.GM = 1, SCR.TE = 1 or SCR.RE = 1 When SCI2.SCMR.SMIF = 0: While SMR.CM = 0, SCR.CKE[1:0] = 01 or SMR.CM = 1, SCR.CKE[1] = 0, SCR.TE = 1 or SCR.RE = 1
	PORTB	PB7		PORTB.DDR.B7 = 1
PD3	GPT2	GTIOC2A-B	PFDGPT.GPTS = 1	(The signal output state is specified by the peripheral module settings.)
	SCI1	TXD1		SCI1.SCR.TE = 1
	PORTD	PD3		PORTD.DDR.B3 = 1

Table 15.20 Output Enable Settings for Each Port (80-pin LQFP) (4 / 4)

Port	Module Name	Output Signal Name	Port Function Register Settings	Peripheral Module Settings
PD4	GPT1	GTIOC1B-B	PFDGPT.GPTS = 1	(The signal output state is specified by the peripheral module settings.)
	SCI1	SCK1		When SCI1.SCMR.SMIF = 1: While SMR.GM = 0, SCR.CKE[1:0] = 01 or SMR.GM = 1, SCR.TE = 1 or SCR.RE = 1 When SCI1.SCMR.SMIF = 0: While SMR.CM = 0, SCR.CKE[1:0] = 01 o r SMR.CM = 1, SCR.CKE[1] = 0, SCR.TE = 1 or SCR.RE = 1
	PORTD	PD4		PORTD.DDR.B4 = 1
PD5	GPT1	GTIOC1A-B	PFDGPT.GPTS = 1	(The signal output state is specified by the peripheral module settings.)
	PORTD	PD5		PORTD.DDR.B5 = 1
PD6	GPT0	GTIOC0B-B	PFDGPT.GPTS = 1	(The signal output state is specified by the peripheral module settings.)
	PORTD	PD6		PORTD.DDR.B6 = 1
PD7	CAN	CTX-C	PFJCAN.CANE = 1 PFJCAN.CANS[1:0] = 10	(The signal output state is specified by the peripheral module settings.)
	GPT0	GTIOC0A-B	PFDGPT.GPTS = 1	(The signal output state is specified by the peripheral module settings.)
	PORTD	PD7		PORTD.DDR.B7 = 1
PE0	PORTE	PE0		PORTE.DDR.B0 = 1
PE3	PORTE	PE3		PORTE.DDR.B3 = 1
PE4	PORTE	PE4		PORTE.DDR.B4 = 1

15.3.5 Treatment of Unused Pins

The treatment of unused pins is listed in Table 15.21.

Table 15.21 Treatment of Unused Pin (80-pin LQFP)

Pin Name	Treatment
EMLE	Connect this pin to Vss via a pull-down resistor.
MD1, MD0	(Always used as mode pins)
MDE	(Always used as mode pins)
RES#	Connect this pin to Vcc via a pull-up resistor.
PE2/NMI/POE10#-A	Connect this pin to Vcc via a pull-up resistor.
EXTAL	(Always used as a clock pin)
XTAL	Leave these pins open.
Port to 3, 7, 9, A, B, D, E	• Connect these pins to Vcc via a pull-up resistor or to Vss via a pull-down resistor. • These pins can be left while PORTn.ICR is in the initial state (the input buffer disabled)*1.
Port 4	• Connect these pins to AVCC0 via a pull-up resistor or to AVSS0 via a pull-down resistor. • These pins can be left while PORTn.ICR is in the initial state (the input buffer disabled)*1.
Port 6	• Connect these pins to AVCC via a pull-up resistor or to AVSS via a pull-down resistor • These pins can be left while PORTn.ICR is in the initial state (the input buffer disabled)*1.
VREFH0	Connect this pin to AVCC0.
VREFL0	Connect this pin to AVSS0.

Note 1. Do not change the initial value of PORTn.ICR. Changing the initial value may generate shoot-through current.

15.4 I/O Port [for 64-Pin LQFP]

The RX62T Group (64-Pin LQFP) has 10 I/O ports (ports 1 to 4, 7, 9, A, B, D, E), which handle 37 I/O pins.

15.4.1 Overview

Table 15.22 gives the specifications of the I/O ports and Table 15.23 lists I/O ports and pin functions.

Table 15.22 Specifications of I/O Ports (64-Pin LQFP)

Item	Description
I/O pins	37
Input pins	9
Number of ports	10 (1 to 4, 7, 9, A, B, D, and E)
Open drain outputs	2 (RIIC pin)
Large-current output	6 (MTU3 pin and GPT pin)
Schmitt trigger input pins	All port inputs, CAN inputs, IRQ inputs, MTU3 inputs, POE3 inputs, RIIC inputs, SCI inputs, A/D trigger inputs, NMI inputs, GPT inputs, and LIN inputs
Others	Each pin is capable of driving a capacitive load of 30 pF in the case of a TTL load. When configured as an output, a pin is capable of driving a Darlington transistor. A pin is always capable of reading the status of the pins.

Table 15.23 Port Functions (64-Pin LQFP) (1 / 2)

Port	Description	Bit	Function			CMOS Input	Schmitt Trigger Input	Open Drain Output Capability	Large-Current Output
			I/O	Input	Output				
Port 1	General I/O port pins, MTU3 inputs, and interrupt inputs	0	P10	MTCLKD-B/IRQ0-A		—	All input functions	—	—
		1	P11	MTCLKC-B/IRQ1-A			All input functions		
Port 2	General I/O port pins, RSPI I/O signal, LIN I/O signal, and CAN I/O signal	2	P22/MISO-A	LRX/CRX-B		MISO-A	P22/LRX/ CRX-B	—	—
		3	P23/MOSI-A		LTX/CTX-B	MOSI-A	P23		
		4	P24/RSPCK-A			RSPCK-A	P24		
Port 3	General I/O port pins, MTU3 I/O signal, and RSPI I/O	0	P30/MTIOC0B-B/ SSL0-A	MTCLKD-A		SSL0-A	P30/ MTIOC0B-B/ MTCLKD-A	—	—
		1	P31/MTIOC0A-B	MTCLKC-A	SSL1-A	—	All input functions		
		2	P32/MTIOC3C	MTCLKB-A	SSL2-A		All input functions		
		3	P33/MTIOC3A	MTCLKA-A	SSL3-A		All input functions		
Port 4	A/D converter inputs and general input port pins	0	P40	P40/AN000		—	P40	—	—
		1	P41	P41/AN001			P41		
		2	P42	P42/AN002			P42		
		3	P43	P43/AN003/ CVREFL			P43		
		4	P44	P44/AN100			P44		
		5	P45	P45/AN101			P45		
		6	P46	P46/AN102			P46		
		7	P47	P47/AN103/ CVREFH			P47		
Port 7	General I/O port pins, POE3 inputs, interrupt inputs, MTU3 I/O signal, and GPT I/O signal	0	P70	POE0#/IRQ5		—	All input functions	—	—
		1	P71/MTIOC3B/ GTIOC0A-A				All input functions		√
		2	P72/MTIOC4A/ GTIOC1A-A				All input functions		√
		3	P73/MTIOC4B/ GTIOC2A-A				All input functions		√
		4	P74/MTIOC3D/ GTIOC0B-A				All input functions		√√
		5	P75/MTIOC4C/ GTIOC1B-A				All input functions		√
		6	P76/MTIOC4D/ GTIOC2B-A				All input functions		√
Port 9	General I/O port pins and MTU3 I/O signal	1	P91/MTIOC7C			—	All input functions	—	—
		2	P92/MTIOC6D				All input functions		
		3	P93/MTIOC7B				All input functions		
		4	P94/MTIOC7A				All input functions		

Table 15.23 Port Functions (64-Pin LQFP) (2 / 2)

Port	Description	Bit	Function			CMOS Input	Schmitt Trigger Input	Open Drain Output Capability	Large-Current Output
			I/O	Input	Output				
Port A	General I/O port pins, MTU3 I/O signal, RSPI I/O signal, and A/D converter inputs	2	PA2/MTIOC2B		SSL1-B	—	All input functions	—	—
		3	PA3/MTIOC2A/ SSL0-B			SSL0-B	PA3/ MTIOC2A		
		4	PA4/MTIOC1B/ RSPCK-B	ADTRG0#-A		RSPCK-B	PA4/ MTIOC1B/ ADTRG0#-A		
		5	PA5/MTIOC1A/ MISO-B	ADTRG1#-A		MISO-B	PA5/ MTIOC1A/ ADTRG1#-A		
Port B	General I/O port pins, MTU3 I/O signal, RSPI I/O signal, RIIC I/O signal, SCI I/O signal, GPT inputs, POE3 inputs, interrupt inputs, and CAN I/O signal	0	PB0/MTIOC0D/ MOSI-B			MOSI-B	PB0/ MTIOC0D	—	—
		1	PB1/MTIOC0C/ SCL	RXD0		—	All input functions	√ (SCL only)	—
		2	PB2/MTIOC0B-A/ SDA		TXD0		All input functions	√ (SDA only)	—
		3	PB3/MTIOC0A-A/ SCK0				All input functions	—	—
		4	PB4	GTETRG/ POE8#/IRQ3			All input functions		
		5	PB5		TXD2-A/ CTX-A		All input functions		
		6	PB6	RXD2-A/CRX-A			All input functions		
		7	PB7/SCK2-A				All input functions		
Port D	General I/O port pins, GPT I/O signal, SCI I/O signal, and on-chip emulator I/O signal	3	PD3/GTIOC2A-B		TXD1/TDO	—	All input functions	—	—
		4	PD4/GTIOC1B-B/ SCK1	TCK		—	All input functions		
		5	PD5/GTIOC1A-B	RXD1/TDI		—	All input functions		
		6	PD6/GTIOC0B-B	TMS			All input functions		
		7	PD7/GTIOC0A-B	TRST#		—	All input functions		
Port E	General I/O port pins, POE3 inputs, and interrupt inputs	2		PE2/POE10#-A/ NMI			All input functions	—	—

15.4.2 Register Descriptions

Table 15.24 lists registers of I/O ports, and Table 15.25 lists valid bits in each register

Table 15.24 Registers of I/O Ports (64-Pin LQFP)

Port Symbol	Register Name	Register Symbol	Value after Reset	Address	Access Size
PORT1	Data direction register	DDR	00h	0008 C001h	8
	Data register	DR	00h	0008 C021h	8
	Port register	PORT	Undefined	0008 C041h	8
	Input buffer control register	ICR	00h	0008 C061h	8
PORT2	Data direction register	DDR	00h	0008 C002h	8
	Data register	DR	00h	0008 C022h	8
	Port register	PORT	Undefined	0008 C042h	8
	Input buffer control register	ICR	00h	0008 C062h	8
PORT3	Data direction register	DDR	00h	0008 C003h	8
	Data register	DR	00h	0008 C023h	8
	Port register	PORT	Undefined	0008 C043h	8
	Input buffer control register	ICR	00h	0008 C063h	8
PORT4	Port register	PORT	Undefined	0008 C044h	8
	Input buffer control register	ICR	00h	0008 C064h	8
PORT7	Data direction register	DDR	00h	0008 C007h	8
	Data register	DR	00h	0008 C027h	8
	Port register	PORT	Undefined	0008 C047h	8
	Input buffer control register	ICR	00h	0008 C067h	8
PORT9	Data direction register	DDR	00h	0008 C009h	8
	Data register	DR	00h	0008 C029h	8
	Port register	PORT	Undefined	0008 C049h	8
	Input buffer control register	ICR	00h	0008 C069h	8
PORTA	Data direction register	DDR	00h	0008 C00Ah	8
	Data register	DR	00h	0008 C02Ah	8
	Port register	PORT	Undefined	0008 C04Ah	8
	Input buffer control register	ICR	00h	0008 C06Ah	8
PORTB	Data direction register	DDR	00h	0008 C00Bh	8
	Data register	DR	00h	0008 C02Bh	8
	Port register	PORT	Undefined	0008 C04Bh	8
	Input buffer control register	ICR	00h	0008 C06Bh	8
PORTD	Data direction register	DDR	00h	0008 C00Dh	8
	Data register	DR	00h	0008 C02Dh	8
	Port register	PORT	Undefined	0008 C04Dh	8
	Input buffer control register	ICR	00h	0008 C06Dh	8
PORTE	Port register	PORT	Undefined	0008 C04Eh	8
IOPORT	Port function register C	PFCMTU	00h	0008 C10Ch	8
	Port function register D	PFDGPT	00h	0008 C10Dh	8
	Port function register G	PFGSPI	00h	0008 C110h	8
	Port function register H	PFHSPI	00h	0008 C111h	8
	Port function register J	PFJCAN	00h	0008 C113h	8
	Port function register K	PFKLIN	00h	0008 C114h	8
	Port function register M	PFMPOE	00h	0008 C116h	8

Table 15.25 Valid Bits in Each Register 64-Pin LQFP)

Register Symbol	b7	b6	b5	b4	b3	b2	b1	b0
PORT1.DDR	x	x	x	x	x	x	√	x
PORT2.DDR	x	x	x	√	√	√	x	x
PORT3.DDR	x	x	x	x	√	√	√	√
PORT7.DDR	x	√	√	√	√	√	√	√
PORT9.DDR	x	x	x	√	√	√	√	x
PORTA.DDR	x	x	√	√	√	√	x	x
PORTB.DDR	√	√	√	√	√	√	√	√
PORTD.DDR	√	√	√	√	√	x	x	x
PORT1.DR	x	x	x	x	x	x	√	√
PORT2.DR	x	x	x	√	√	√	x	x
PORT3.DR	x	x	x	x	√	√	√	√
PORT7.DR	x	√	√	√	√	√	√	√
PORT9.DR	x	x	x	√	√	√	√	x
PORTA.DR	x	x	√	√	√	√	x	x
PORTB.DR	√	√	√	√	√	√	√	√
PORTD.DR	√	√	√	√	√	x	x	x
PORT1.PORT	x	x	x	x	x	x	√	√
PORT2.PORT	x	x	x	√	√	√	x	x
PORT3.PORT	x	x	x	x	√	√	√	√
PORT4.PORT	√	√	√	√	√	√	√	√
PORT7.PORT	x	√	√	√	√	√	√	√
PORT9.PORT	x	x	x	√	√	√	√	x
PORTA.PORT	x	x	√	√	√	√	x	x
PORTB.PORT	√	√	√	√	√	√	√	√
PORTD.PORT	√	√	√	√	√	x	x	x
PORTE.PORT	x	x	x	x	x	√	x	x
PORT1.ICR	x	x	x	x	x	x	√	√
PORT2.ICR	x	x	x	√	√	√	x	x
PORT3.ICR	x	x	x	x	√	√	√	√
PORT4.ICR	√	√	√	√	√	√	√	√
PORT7.ICR	x	√	√	√	√	√	√	√
PORT9.ICR	x	x	x	√	√	√	√	x
PORTA.ICR	x	x	√	√	√	√	x	x
PORTB.ICR	√	√	√	√	√	√	√	√
PORTD.ICR	√	√	√	√	√	x	x	x
IOPORT.PFCMTU	√	√	x	x	x	x	√	√
IOPORT.PFDGPT	x	x	x	x	x	x	x	√
IOPORT.PFGSPI	√	√	√	√	√	√	√	x
IOPORT.PFHSPI	x	x	x	x	x	x	√	√
IOPORT.PFJCAN	√	√	x	x	x	x	x	√
IOPORT.PFKLIN	x	x	x	x	x	x	x	√
IOPORT.PFMPOE	x	x	x	x	√	√	x	√

√: Enabled bit, x: Disabled bit (Reserved)

15.4.2.1 Data Direction Register (DDR)

Address: PORT1.DDR 0008 C001h, PORT2.DDR 0008 C002h, PORT3.DDR 0008 C003h, PORT7.DDR 0008 C007h, PORT9.DDR 0008 C009h, PORTA.DDR 0008 C00Ah, PORTB.DDR 0008 C00Bh, PORTD.DDR 0008 C00Dh, PORTE.DDR 0008 C00Eh

	b7	b6	b5	b4	b3	b2	b1	b0
	B7	B6	B5	B4	B3	B2	B1	B0
Value after reset:	0	0	0	0	0	0	0	0

Notes:

1. The lower two bits are valid and the upper six bits are reserved in PORT1.DDR.
   Bit 4 to bit 2 are valid and bit 7 to bit 5, bit 1, and bit 0 are reserved in PORT2.DDR.
   The lower four bits are valid and the upper four bits are reserved in PORT3.DDR.
   The lower seven bits are valid and the highest order bit is reserved in PORT7.DDR.
   Bit 4 to bit 1 are valid and, bit 7 to bit 5, and bit 0 are reserved in PORT9.DDR.
   Bit 5 to bit 2 are valid and, bit 7, bit 6, bit 1, bit 0 are reserved in PORTA.DDR.
   The upper five bits are valid and the lower three bits are reserved in PORTD.DDR.
2. The reserved bits are read as 0. The write value should always be 0.

Bit	Symbol	Bit Name	Description	R/W
b0	B0	Pn0 I/O Select (n=1 to 3, 7, 9, A, B, D, E)	0: An input pin 1: An output pin	R/W
b1	B1	Pn1 I/O Select		R/W
b2	B2	Pn2 I/O Select		R/W
b3	B3	Pn3 I/O Select		R/W
b4	B4	Pn4 I/O Select		R/W
b5	B5	Pn5 I/O Select		R/W
b6	B6	Pn6 I/O Select		R/W
b7	B7	Pn7 I/O Select		R/W

n = 1 to 3, 7, 9, A, B, D, E

Each PORTn.DDR is used to select the input or output direction for individual pins of the corresponding port that have been configured to function as general I/O pins.
Each bit of a PORTn.DDR (n=1 to 3, 7, 9, A, B, D, E) corresponds to a pin of Pn, and the settings can change from bit to bit.

15.4.2.2 Data Register (DR)

Address: PORT1.DR 0008 C021h, PORT2.DR 0008 C022h, PORT3.DR 0008 C023h, PORT7.DR 0008 C027h, PORT9.DR 0008 C029h, PORTA.DR 0008 C02Ah, PORTB.DR 0008 C02Bh, PORTD.DR 0008 C02Dh, PORTE.DR 0008 C02Eh

	b7	b6	b5	b4	b3	b2	b1	b0
	B7	B6	B5	B4	B3	B2	B1	B0
Value after reset:	0	0	0	0	0	0	0	0

Notes:

1. The lower two bits are valid and the upper six bits are reserved in PORT1.DR.
   Bit 4 to bit 2 are valid and bit 7 to bit 5, bit 1, and bit 0 are reserved in PORT2.DR.
   The lower four bits are valid and the upper four bits are reserved in PORT3.DR.
   The lower seven bits are valid and the highest order bit is reserved in PORT7.DR.
   Bit 4 to bit 1 are valid and bit 7 to bit 5, and bit 0 are reserved in PORT9.DR.
   Bit 5 to bit 2 are valid and bit 7, bit 6, bit 1, and bit 0 are reserved in PORTA.DR.
   The upper five bits are valid, the lower three bits are reserved in PORTD.DR.
2. The reserved bits are read as 0. The write value should always be 0.

Bit	Symbol	Bit Name	Description	R/W
b0	B0	Pn0 Output Data Store (n=1 to 3, 7, 9, A, B, D, E)	Output data are stored.	R/W
b1	B1	Pn1 Output Data Store		R/W
b2	B2	Pn2 Output Data Store		R/W
b3	B3	Pn3 Output Data Store		R/W
b4	B4	Pn4 Output Data Store		R/W
b5	B5	Pn5 Output Data Store		R/W
b6	B6	Pn6 Output Data Store		R/W
b7	B7	Pn7 Output Data Store		R/W

n = 1 to 3, 7, 9, A, B, D, E

Each PORTn.DR (n=1 to 3, 7, 9, A, B, D, E) stores the output data from the individual pins of the corresponding port used as a general I/O port.

15.4.2.3 Port Register (PORT)

Address: PORT1.PORT 0008 C041h, PORT2.PORT 0008 C042h, PORT3.PORT 0008 C043h, PORT4.PORT 0008 C044h, PORT7.PORT 0008 C047h, PORT9.PORT 0008 C049h, PORTA.PORT 0008 C04Ah, PORTB.PORT 0008 C04Bh, PORTD.PORT 0008 C04Dh, PORTE.PORT 0008 C04Eh

	b7	b6	b5	b4	b3	b2	b1	b0
	B7	B6	B5	B4	B3	B2	B1	B0
Value after reset:	x	x	x	x	x	x	x	x

Notes:

1. The lower two bits are valid and the upper six bits are reserved in PORT1.PORT.
   Bit 4 to bit 2 are valid and bit 7 to bit 5, bit 1, and bit 0 are reserved in PORT2.PORT.
   The lower four bits are valid and the upper four bits are reserved in PORT3.PORT.
   The lower seven bits are valid and the highest order bit is reserved in PORT7.PORT.
   Bit 4 to bit 1 are valid and bit 7 to bit 5, and bit 0 are reserved in PORT9.PORT.
   Bit 5 to bit 2 are valid and bit 7, bit 6, bit 1, and bit 0 are reserved in PORTA.PORT.
   The upper five bits are valid and the lower three bits are reserved in PORTD.PORT.
   Bit 2 is valid and bit 7 to bit 3, bit 1, and bit 0 are reserved in PORTE.PORT.
2. The reserved bits are read as 1. Writing to these bits has no effect.

Bit	Symbol	Bit Name	Description	R/W
b0	B0	Pn0 (n=1 to 4, 7, 9, A, B, D, E)	Individual pin states of the corresponding port are reflected.	R
b1	B1	Pn1		R
b2	B2	Pn2		R
b3	B3	Pn3		R
b4	B4	Pn4		R
b5	B5	Pn5		R
b6	B6	Pn6		R
b7	B7	Pn7		R

n = 1 to 4, 7, 9, A, B, D, E

PORT reflects individual pin states of the corresponding port.

When a PORTn.PORT (n = 1 to 4, 7, 9, A, B, D, E) is read, the corresponding pin states are read out to here.

15.4.2.4 Input Buffer Control Register (ICR)

Address: PORT1.ICR 0008 C061h, PORT2.ICR 0008 C062h, PORT3.ICR 0008 C063h, PORT4.ICR 0008 C064h, PORT7.ICR 0008 C067h, PORT9.ICR 0008 C069h, PORTA.ICR 0008 C06Ah, PORTB.ICR 0008 C06Bh, PORTD.ICR 0008 C06Dh

	b7	b6	b5	b4	b3	b2	b1	b0
	B7	B6	B5	B4	B3	B2	B1	B0
Value after reset:	0	0	0	0	0	0	0	0

Notes:

1. The lower two bits are valid and the upper six bits are reserved in PORT1.ICR.
   Bit 4 to bit 2 are valid and bit 7 to bit 5, bit 1, and bit 0 are reserved in PORT2.ICR.
   The lower four bits are valid and the upper four bits are reserved in PORT3.ICR
   The lower seven bits are valid and the highest order bit is reserved in PORT7.ICR
   Bit 4 to bit 1 are valid and bit 7 to bit 5, and bit 0 are reserved in PORT9.ICR.
   Bit 5 to bit 2 are valid and bit 7, bit 6, bit 1, and bit 0 are reserved in PORTA.ICR.
   The upper five bits are valid and lower three bits are reserved in PORTD.ICR.
2. The reserved bits are read as 0. The write value should always be 0.

Bit	Symbol	Bit Name	Description	R/W
b0	B0*1	Pn0 Input Buffer Control (n=1 to 4, 7, 9, A, B, D)	0: The input buffer for the corresponding pin is disabled. 1: The input buffer for the corresponding pin is enabled.	R/W
b1	B1*1	Pn1 Input Buffer Control		R/W
b2	B2*1	Pn2 Input Buffer Control		R/W
b3	B3*1	Pn3 Input Buffer Control		R/W
b4	B4*1	Pn4 Input Buffer Control		R/W
b5	B5*1	Pn5 Input Buffer Control		R/W
b6	B6*1	Pn6 Input Buffer Control		R/W
b7	B7*1	Pn7 Input Buffer Control		R/W

n = 1 to 4, 7, 9, A, B, D, E

Note 1. For pins being used as input pins for peripheral modules, set the corresponding bits to 1. Set the bits corresponding to pins that are not being used for their input functions or are being used as analog input pins to 0.

Each PORTn.ICR controls the input buffers for the individual pins of the corresponding port.

Each bit of a PORTn.ICR (n = 1 to 4, 7, 9, A, B, D) corresponds to a pin of PORTn, and the settings can change from bit to bit.

When to be used as an input pin for the peripheral module, the input buffer for the corresponding pin should be enabled beforehand by setting the PORTn.ICR bit to 1. If this register is used as an input pin for the peripheral module while the PORTn.ICR bit is 0, the input signal to the peripheral module is fixed high.

When a PORTn.ICR register is read, the pin states of the corresponding port are read out regardless of the values in PORTn.ICR. For bits where the value in PORTn.ICR is 0, however, the value may not reflect the pin state on the corresponding peripheral module side.

Changes in the settings of a PORTn.ICR may generate edges internally, depending on the pin state. For this reason, change the settings of PORTn.ICR while the corresponding input pins are not in use. For example, in the case of IRQi (i = 0 to 7) inputs, change settings of the corresponding PORTn.ICR with interrupts disabled by clearing the IR flag in IRi (i = 64 to 71 ("i" shows an interrupt vector number of the IRQ)) of the interrupt controller (ICU) to 0, and then enable the corresponding interrupts. If a change to a PORTn.ICR setting does generate an edge, negate the edge.

15.4.2.5 Port Function Register C (PFCMTU)

Address: 0008 C10Ch

	b7	b6	b5	b4	b3	b2	b1	b0
	TCLKS[1:0]		—	—	—	—	MTUS1	MTUS0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	MTUS0	MTU3 Pin Select 0	0:PB3 is designated as the MTIOC0A-A pin. 1:P31 is designated as the MTIOC0A-B pin.	R/W
b1	MTUS1	MTU3 Pin Select 1	0:PB2 is designated as the MTIOC0B-A pin. 1:P30 is designated as the MTIOC0B-B pin.	R/W
b5-b2	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7 to b6	TCLKS[1:0]	MTCLK Pin Select	b7 b6 0 0:P33 is designated as the MTCLKA-A pin. P32 is designated as the MTCLKB-A pin. P31 is designated as the MTCLKC-A pin. P30 is designated as the MTCLKD-A pin. 0 1:P11 is designated as the MTCLKC-B pin. P10 is designated as the MTCLKD-B pin. (MTCLKA pin and MTCLKB pins cannot be selected.) 1 0:Setting prohibited 1 1:Setting prohibited	R/W

PFCMTU is used to select pins for MTU3.

MTUSi Bit (MTU3 Pin Select) (i = 0 and 1)

Each bit selects a pin for an MTU3 input/output.

TCLKS[1:0] Bit (MTCLK Pin Select)

This bit selects a pin for a MTCLK input of the MTU3.

15.4.2.6 Port Function Register D (PFDGPT)

Address: 0008 C10Dh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	GPTS
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	GPTS	GPT Pin Select	0:P71 is designated as the GTIOC0A-A pin. P74 is designated as the GTIOC0B-A pin. P72 is designated as the GTIOC1A-A pin. P75 is designated as the GTIOC1B -A pin. P73 is designated as the GTIOC2A-A pin. P76 is designated as the GTIOC2B-A pin. 1:PD7 is designated as the GTIOC0A-B pin. PD6 is designated as the GTIOC0B-B pin. PD5 is designated as the GTIOC1A-B pin. PD4 is designated as the GTIOC1B-B pin. PD3 is designated as the GTIOC2A-B pin. Note that the GTIOC2B-B pin is not selectable.	R/W
b7 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

PFDGPT is used to select a pin for GPT.

GPTS Bit (GPTI/O Pin Select)

Each bit selects a pin for a GPT input/output.

15.4.2.7 Port Function Register G (PFGSPI)

Address: 0008 C110h

	b7	b6	b5	b4	b3	b2	b1	b0
	SSL3E	SSL2E	SSL1E	SSL0E	MISOE	MOSIE	RSPCKE	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b1	RSPCKE	RSPCK Output Enable	0:RSPCK pin is disabled. 1:RSPCK pin is enabled.	R/W
b2	MOSIE	MOSI Output Enable	0:MOSI pin is disabled. 1:MOSI pin is enabled.	R/W
b3	MISOE	MISO Output Enable	0:MISO pin is disabled. 1:MISO pin is enabled.	R/W
b4	SSL0E	SSL0 Output Enable	0:SSL0 pin is disabled. 1:SSL0 pin is enabled.	R/W
b5	SSL1E	SSL1 Output Enable	0:SSL1 pin is disabled. 1:SSL1 pin is enabled.	R/W
b6	SSL2E	SSL2 Output Enable	0:SSL2 pin is disabled. 1:SSL2 pin is enabled.	R/W
b7	SSL3E	SSL3 Output Enable	0:SSL3 pin is disabled. 1:SSL3 pin is enabled.	R/W

PFGSPI is used to select I/O pins for RSPI.

RSPCKE Bit (RSPCK Output Enable)

This bit enables or disables the output of the RSPCK pin. Set this bit to 1 to use the RSPCK pin.

MOSIE Bit (MOSI Output Enable)

This bit enables or disables the output of the MOSI pin. Set this bit to 1 to use the MOSI pin.

MISOE Bit (MISO Output Enable)

This bit enables or disables the output of the MISO pin. Set this bit to 1 to use the MISO pin.

SSL0E Bit (SSL0 Enable)

This bit enables or disables the output of the SSL0 pin. Set this bit to 1 to use the SSL0 pin.

SSL0E Bit (SSL0 Output Enable)

This bit enables or disables the output of the SSL1 pin. Set this bit to 1 to use the SSL1 pin.

SSL1E Bit (SSL1 Output Enable)

This bit enables or disables the output of the SSL1 pin. Set this bit to 1 to use the SSL1 pin.

SSL2E Bit (SSL2 Output Enable)

This bit enables or disables the output of the SSL2 pin. Set this bit to 1 to use the SSL2 pin.

SSL3E Bit (SSL3 Output Enable)

This bit enables or disables the output of the SSL3 pin. Set this bit to 1 to use the SSL3 pin.

15.4.2.8 Port Function Register H (PFHSPI)

Address: 0008 C111h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	RSPIS[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1 to b0	RSPIS[1:0]	RSPI Pin Select	b1 b0 0 0:P22 is designated as the MISO-A pin. P23 is designated as the MOSI-A pin. P24 is designated as the RSPCK-A pin. P30 is designated as the SSL0-A pin. P31 is designated as the SSL1-A pin. P32 is designated as the SSL2-A pin. P33 is designated as the SSL3-A pin. 0 1:PA5 is designated as the MISO-B pin. PB0 is designated as the MISO-B pin. PA4 is designated as the RSPCK-B pin. PA3 is designated as the SSL0-B pin. PA2 is designated as the SSL1-B pin. (SSL2 pin and SSL3 pins cannot be selected.) 1 0:Setting prohibited 1 1:Setting prohibited	R/W
b7 to b4	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

PFHSPI is used to select I/O pins for RSPI channel.

RSPIS[1:0] Bit (RSPI Pin Select)

This bit selects a pin for an RSPI input/output.

As an enable bit is provided for each RSPI input/output pin, the input/output pin is selectable while the corresponding enable bit is 1. Otherwise, the pin cannot be selected.

15.4.2.9 Port Function Register J (PFJCAN)

Address: 0008 C113h

	b7	b6	b5	b4	b3	b2	b1	b0
	CANS[1:0]		—	—	—	—	—	CANE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	CANE	CAN Pin Enable	0: The CTX and CRX pins are disabled. 1: The CTX and CRX pins are enabled.	R/W
b5 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7 to b6	CANS[1:0]	CAN Pin Select	b7 b6 0 0:PB5 is designated as the CTX-A pin. PB6 is designated as the CRX-A pin. 0 1:P23 is designated as the CTX-B pin. P22 is designated as the CRX-B pin. 1 0:Setting prohibited 1 1:Setting prohibited	R/W

PFJCAN is used to select I/O pins for the CAN.

CANE Bit (CAN Pin Enable)

This bit enables or disables the CAN pin. Set this bit to 1 to use the CAN pin.

CANS[1:0] Bit (CAN Pin Select)

These bits select I/O pins for the CAN.

15.4.2.10 Port Function Register K (PFKLIN)

Address: 0008 C114h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	LINE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	LINE	LIN Pin Enable	0:LTX and LRX pins are disabled. 1:LTX and LRX pins are enabled.	R/W
b7 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

PFKLIN is used to set I/O pins for the LIN.

LINE Bit (LIN Pin Enable)

This bit enables or disables the LIN pin. Set this bit to 1 to use the LIN pin.

15.4.2.11 Port Function Register M (PFMPOE)

Address: 0008 C116h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	POE10E	POE8E	—	POE0E
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	POE0E	POE0# Input Enable	0:Designated as an I/O port pin 1:Designated as the POEn# input pin	R/W*1
b1	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b2	POE8E	POE8# Input Enable	0:Designated as an I/O port pin 1:Designated as the POE8# input pin.	R/W*1
b3	POE10E	POE10# Input Enable	0:Designated as an I/O port pin 1:Designated as the POE10# input pin.	R/W*1
b7 to b4	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

Note 1. The first round of writing after a reset is enabled; though subsequent writing is not allowed.

PFMPOE enables or disables POEn# input pins.
To prevent the error in the system, be sure to write to this register after a reset.
The first round of writing after a reset is only enabled.

POEnE Bit (POEn# Input Enable) (n = 0, 8, 10)

Each bit enables or disables the corresponding POEn# input.
To use POEn#, set the corresponding POEnE bit to 1.

15.4.3 Settings of Ports

When individual pins for peripheral modules are enabled, the settings for each port are modified.
An input pin for the peripheral module is specified independently by the peripheral module. To use an input pin for the peripheral module, the corresponding bit in the input buffer control register (PORTn.ICR) should be set to 1 to enable the input buffer, except for the port register read, NMI, and POEn# pin inputs.
The pins that function as output pins and I/O pins should be enabled for respective peripheral modules. If a conflict occurs among the output signal enable settings for peripheral modules, that are multiplexed to the same port, the priority will be handled according to the port-multiplexed priority.
Table 15.26 lists the port-multiplexed priority for peripheral modules.

Table 15.26 Port-Multiplexed Priority for Peripheral Modules (64-Pin LQFP)

Priority		Module Name	Output Pins
High	1	RSPI	RSPCK, MOSI, MISO, SSL0 to SSL3
↑	2	CAN	CTX
	3	LIN	LTX
	4	MTU0 to MTU7	MTIOC0A, MTIOC0B, MTIOC0C, MTIOC0D, MTIOC1A, MTIOC1B, MTIOC2A, MTIOC2B, MTIOC3A, MTIOC3B, MTIOC3C, MTIOC3D, MTIOC4A, MTIOC4B, MTIOC4C, MTIOC4D, MTIOC6D, MTIOC7A, MTIOC7B, MTIOC7C
	5	GPT0 to GPT3	GTIOC0A, GTIOC0B, GTIOC1A, GTIOC1B, GTIOC2A, GTIOC2B
	6	SCI0 to SCI2	SCK0 to SCK2, TXD0 to TXD2
	7	RIIC	SCL, SDA
Low	8	IOPORT	P10 to P11, P22 to P24, P30 to P33, P70 to P76, P91 to P94, PA2 to PA5, PB0 to PB7, PD3 to PD7

15.4.4 List of Output Enable Settings

Table 15.27 lists the output enable settings for each port.
For details on the applicable output signals, see descriptions of the registers for each peripheral module.
Setting the port function register changes the functions of peripheral-module pins with names ending in A and B.

Table 15.27 Output Enable Settings for Each Port (64-pin LQFP) (1 / 4)

Port	Module Name	Output Signal Name	Port Function Register Settings	Peripheral Module Settings
P10	PORT1	P10		PORT1.DDR.B0 = 1
P11	PORT1	P11		PORT1.DDR.B1 = 1
P22	RSPI	MISO-A	PFGSPI.MISOE = 1 PFHSPI.RSPIS[1:0] = 00	(In addition to the pin enable setting, input/output switching function for the peripheral module is provided.)
	PORT2	P22		PORT2.DDR.B2 = 1
P23	RSPI	MOSI-A	PFGSPI.MOSIE = 1 PFHSPI.RSPIS[1:0] = 00	(In addition to the pin enable setting, input/output switching function for the peripheral module is provided.)
	CAN	CTX-B	PFJCAN.CANE =1 PFJCAN.CANS[1:0] = 01	(The signal output state is specified by the peripheral module settings.)
	LIN	LTX	PFKLIN.LINE = 1	(The signal output state is specified by the peripheral module settings.)
	PORT2	P23		PORT2.DDR.B3 = 1
P24	RSPI	RSPCK-A	PFGSPI.RSPCKE = 1 PFHSPI.RSPIS[1:0] = 00	(In addition to the pin enable setting, input/output switching function for the peripheral module is provided.)
	PORT2	P24		PORT2.DDR.B4 = 1
P30	RSPI	SSL0-A	PFGSPI.SSL0E = 1 PFHSPI.RSPIS[1:0] = 00	(In addition to the pin enable setting, input/output switching function for the peripheral module is provided.)
	MTU0	MTIOC0B-B	PFCMTU.MTUS1 = 1	(The signal output state is specified by the peripheral module settings.)
	PORT3	P30		PORT3.DDR.B0 = 1
P31	RSPI	SSL1-A	PFGSPI.SSL1E = 1 PFHSPI.RSPIS[1:0]=00	(The signal output state is specified by the peripheral module settings.)
	MTU0	MTIOC0A-B	PFCMTU.MTUS0 = 1	(The signal output state is specified by the peripheral module settings.)
	PORT3	P31		PORT3.DDR.B1 = 1
P32	RSPI	SSL2-A	PFGSPI.SSL2E = 1 PFHSPI.RSPIS[1:0] = 00	(The signal output state is specified by the peripheral module settings.)
	MTU3	MTIOC3C		(The signal output state is specified by the peripheral module settings.)
	PORT3	P32		PORT3.DDR.B2 = 1
P33	RSPI	SSL3-A	PFGSPI.SSL3E =1 PFHSPI.RSPIS[1:0] = 00	(The signal output state is specified by the peripheral module settings.)
	MTU3	MTIOC3A		(The signal output state is specified by the peripheral module settings.)
	PORT3	P33		PORT3.DDR.B3 = 1
P70	PORT7	P70		PORT7.DDR.B0 = 1
P71	MTU3	MTIOC3B		(The signal output state is specified by the peripheral module settings.)
	GPT0	GTIOC0A-A	PFDGPT.GPTS = 0	(The signal output state is specified by the peripheral module settings.)
	PORT7	P71		PORT7.DDR.B1 = 1

Table 15.27 Output Enable Settings for Each Port (64-pin LQFP) (2 / 4)

Port	Module Name	Output Signal Name	Port Function Register Settings	Peripheral Module Settings
P72	MTU4	MTIOC4A		(The signal output state is specified by the peripheral module settings.)
	GPT1	GTIOC1A-A	PFDGPT.GPTS = 0	(The signal output state is specified by the peripheral module settings.)
	PORT7	P72		PORT7.DDR.B2 = 1
P73	MTU4	MTIOC4B		(The signal output state is specified by the peripheral module settings.)
	GPT2	GTIOC2A-A	PFDGPT.GPTS=0	(The signal output state is specified by the peripheral module settings.)
	PORT7	P73		PORT7.DDR.B3 = 1
P74	MTU3	MTIOC3D		(The signal output state is specified by the peripheral module settings.)
	GPT0	GTIOC0B-A	PFDGPT.GPTS=0	(The signal output state is specified by the peripheral module settings.)
	PORT7	P74		PORT7.DDR.B4 = 1
P75	MTU4	MTIOC4C		(The signal output state is specified by the peripheral module settings.)
	GPT1	GTIOC1B-A	PFDGPT.GPTS = 0	(The signal output state is specified by the peripheral module settings.)
	PORT7	P75		PORT7.DDR.B5 = 1
P76	MTU4	MTIOC4D		(The signal output state is specified by the peripheral module settings.)
	GPT2	GTIOC2B-A	PFDGPT.GPTS = 0	(The signal output state is specified by the peripheral module settings.)
	PORT7	P76		PORT7.DDR.B6 = 1
P91	MTU7	MTIOC7C		(The signal output state is specified by the peripheral module settings.)
	PORT9	P91		PORT9.DDR.B1 = 1
P92	MTU6	MTIOC6D		(The signal output state is specified by the peripheral module settings.)
	PORT9	P92		PORT9.DDR.B2 = 1
P93	MTU7	MTIOC7B		(The signal output state is specified by the peripheral module settings.)
	PORT9	P93		PORT9.DDR.B3 = 1
P94	MTU7	MTIOC7A		(The signal output state is specified by the peripheral module settings.)
	PORT9	P94		PORT9.DDR.B4 = 1
PA2	RSPI	SSL1-B	PFGSPI.SSL1E = 1 PFHSPI.RSPIS[1:0] = 01	(The signal output state is specified by the peripheral module settings.)
	MTU2	MTIOC2B		(The signal output state is specified by the peripheral module settings.)
	PORTA	PA2		PORTA.DDR.B2 = 1
PA3	RSPI	SSL0-B	PFGSPI.SSL0E = 1 PFHSPI.RSPIS[1:0] = 01	(In addition to the pin enable setting, input/output switching function for the peripheral module is provided.)
	MTU2	MTIOC2A		(The signal output state is specified by the peripheral module settings.)
	PORTA	PA3		PORTA.DDR.B3 = 1

Table 15.27 Output Enable Settings for Each Port (64-pin LQFP) (3 / 4)

Port	Module Name	Output Signal Name	Port Function Register Settings	Peripheral Module Settings
PA4	RSPI	RSPCK-B	PFGSPI.RSPCKE = 1 PFHSPI.RSPIS[1:0] = 01	(In addition to the pin enable setting, input/output switching function for the peripheral module is provided.)
	MTU1	MTIOC1B		(The signal output state is specified by the peripheral module settings.)
	PORTA	PA4		PORTA.DDR.B4 = 1
PA5	RSPI	MISO-B	PFGSPI.MISOE = 1 PFHSPI.RSPIS[1:0] = 01	(In addition to the pin enable setting, input/output switching function for the peripheral module is provided.)
	MTU1	MTIOC1A		(The signal output state is specified by the peripheral module settings.)
	PORTA	PA5		PORTA.DDR.B5 = 1
PB0	RSPI	MOSI-B	PFGSPI.MOSIE=1 PFHSPI.RSPIS[1:0]=01	(In addition to the pin enable setting, input/output switching function for the peripheral module is provided.)
	MTU0	MTIOC0D		(The signal output state is specified by the peripheral module settings.)
	PORTA	PB0		PORTB.DDR.B0 = 1
PB1	MTU0	MTIOC0C		(The signal output state is specified by the peripheral module settings.)
	RIIC	SCL		RIIC.ICCR1.ICE = 1
	PORTB	PB1		PORTB.DDR.B1 = 1
PB2	MTU0	MTIOC0B-A	PFCMTU.MTUS1 = 0	(The signal output state is specified by the peripheral module settings.)
	SCI0	TXD0		SCI0.SCR.TE = 1
	RIIC	SDA		RIIC.ICCR1.ICE = 1
	PORTB	PB2		PORTB.DDR.B2 = 1
PB3	MTU0	MTIOC0A-A	PFCMTU.MTUS0 = 0	(The signal output state is specified by the peripheral module settings.)
	SCI0	SCK0		When SCI0.SCMR.SMIF = 1: While SMR.GM = 0, SCR.CKE[1:0] = 01 or SMR.GM = 1, SCR.TE = 1 or SCR.RE = 1 When SCI0.SCMR.SMIF = 0: While SMR.CM = 0, SCR.CKE[1:0] = 01 or SMR.CM = 1, SCR.CKE[1] = 0, SCR.TE = 1 or SCR.RE = 1
	PORTB	PB3		PORTB.DDR.B3 = 1
PB4	PORTB	PB4		PORTB.DDR.B4 = 1
PB5	CAN	CTX-A	PFJCAN.CANE = 1 PFJCAN.CANS[1:0] = 00	(The signal output state is specified by the peripheral module settings.)
	SCI2	TXD2-A	PFFSCI.SCI2S = 0	SCI2.SCR.TE = 1
	PORTB	PB5		PORTB.DDR.B5 = 1
PB6	PORTB	PB6		PORTB.DDR.B6 = 1
PB7	SCI2	SCK2-A	PFFSCI.SCI2S = 0	When SCI2.SCMR.SMIF = 1: While SMR.GM = 0, SCR.CKE[1:0] = 01 or SMR.GM = 1, SCR.TE = 1 or SCR.RE = 1 When SCI2.SCMR.SMIF = 0: While SMR.CM = 0, SCR.CKE[1:0] = 01 or SMR.CM = 1, SCR.CKE[1] = 0, SCR.TE = 1 or SCR.RE = 1
	PORTB	PB7		PORTB.DDR.B7=1

Table 15.27 Output Enable Settings for Each Port (64-pin LQFP) (4 / 4)

Port	Module Name	Output Signal Name	Port Function Register Settings	Peripheral Module Settings
PD3	GPT2	GTIOC2A-B	PFDGPT.GPTS = 1	(The signal output state is specified by the peripheral module settings.)
	SCI1	TXD1		SCI1.SCR.TE = 1
	PORTD	PD3		PORTD.DDR.B3 = 1
PD4	GPT1	GTIOC1B-B	PFDGPT.GPTS = 1	(The signal output state is specified by the peripheral module settings.)
	SCI1	SCK1		When SCI1.SCMR.SMIF = 1: While SMR.GM = 0, SCR.CKE[1:0] = 01 or SMR.GM = 1, SCR.TE = 1 or SCR.RE = 1 When SCI1.SCMR.SMIF = 0: While SMR.CM = 0, SCR.CKE[1:0] = 01 or SMR.CM=1, SCR.CKE[1] = 0, SCR.TE = 1 or SCR.RE = 1
	PORTD	PD4		PORTD.DDR.B4 = 1
PD5	GPT1	GTIOC1A-B	PFDGPT.GPTS = 1	(The signal output state is specified by the peripheral module settings.)
	PORTD	PD5		PORTD.DDR.B5 = 1
PD6	GPT0	GTIOC0B-B	PFDGPT.GPTS = 1	(The signal output state is specified by the peripheral module settings.)
	PORTD	PD6		PORTD.DDR.B6 = 1
PD7	GPT0	GTIOC0A-B	PFDGPT.GPTS = 1	(The signal output state is specified by the peripheral module settings.)
	PORTD	PD7		PORTD.DDR.B7 = 1

15.4.5 Treatment of Unused Pins

The treatment of unused pins is listed in Table 15.28.

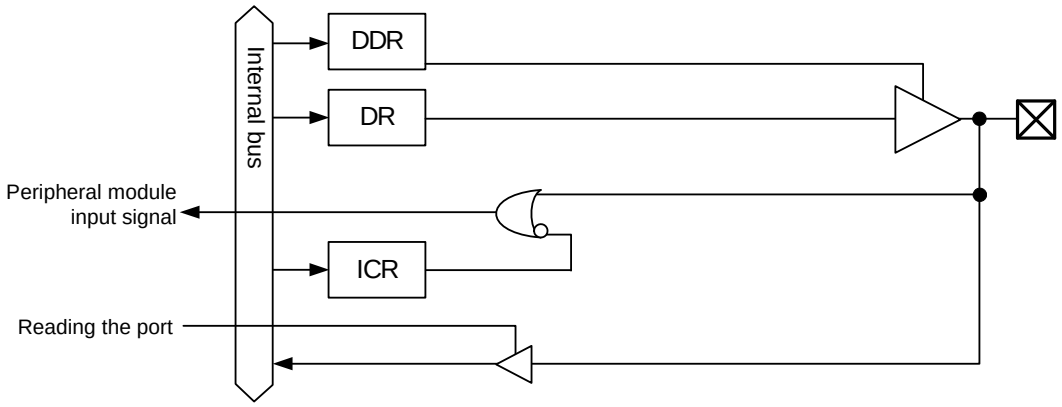
Table 15.28 Treatment of Unused Pin (64-pin LQFP)

Pin Name	Treatment
EMLE	Connect this pin to Vss via a pull-down resistor.
MD1, MD0	(Always used as mode pins)
MDE	(Always used as mode pins)
RES#	Connect this pin to Vcc via a pull-up resistor.
PE2/NMI/POE10#-A	Connect this pin to Vcc via a pull-up resistor.
EXTAL	(Always used as a clock pin)
XTAL	Leave these pins open.
Port 1 to 3, 7, 9, A, B, D, E	Connect these pins to Vcc via a pull-up resistor or to Vss via a pull-down resistor These pins can be left while PORTn.ICR is in the initial state (the input buffer disabled)*1.
Port 4	Connect these pins to AVCC0 via a pull-up resistor or to AVSS0 via a pull-down resistor These pins can be left while PORTn.ICR is in the initial state (the input buffer disabled)*1.
VREFH0	Connect this pin to AVCC0
VREFL0	Connect this pin to AVSS0

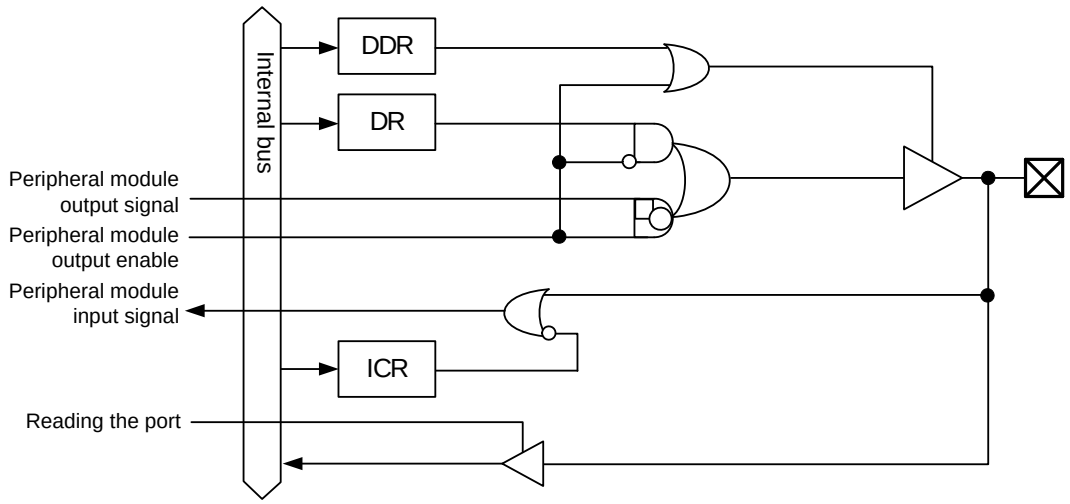
Note 1. Do not change the initial value of PORTn.ICR. Changing the initial value may generate shoot-through current.

15.5 I/O Port Configuration

Port 1 (P10, P11)
Port 2 (P20, P21*1)
Port 7 (P70)
Port 8 (P80*1, *2)
Port 9 (P96*1)
Port B (PB4)
Port E (PE5*1, *2)



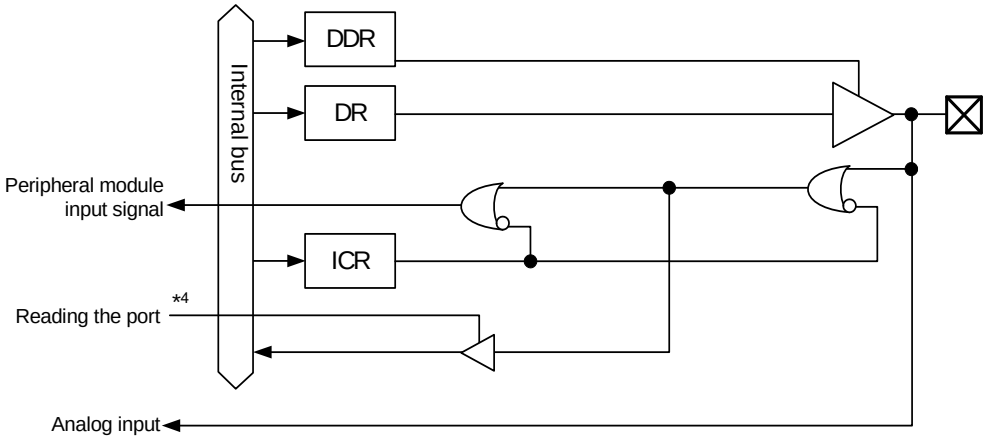
Port 2 (P22 to P24)
Port 3 (P30 to P33)
Port 7 (P71 to P76)
Port 8 (P81, P82*1, *2)
Port 9 (P90*1, *2, P91 to P94, P95*1)
Port A (PA0, PA1*1, *2, PA2 to PA5)
Port B (PB0 to PB3, PB6, PB7)
Port D (PD0 to PD2*1, *2, PD3 to PD7)
Port E (PE0*1, PE3*1, PE4*1)
Port G (PG0 to PG2*1, *2, *3)



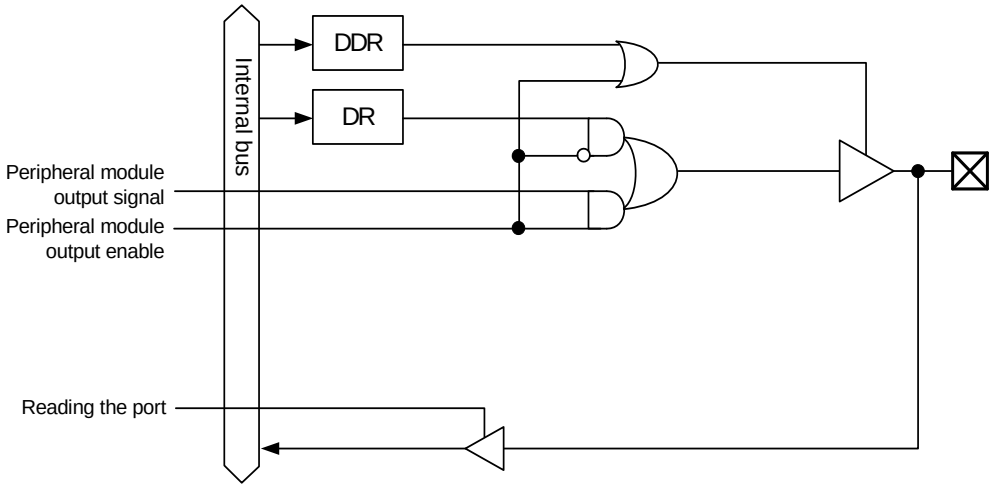
Note 1: Products in the 64-pin LQFP do not have these pins.
Note 2: Products in the 80-pin LQFP do not have these pins.
Note 3: Products in the 100-pin LQFP do not have these pins.

Figure 15.1 I/O Port Configuration (1)

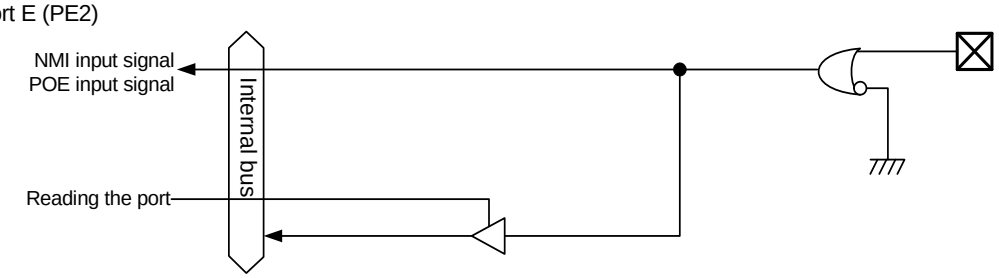
Port 4 (P40 to P47)
Port 5 (P50 to P55*1, *2)
Port 6 (P60 to P63*1, P64*1, *2, P65*1, *2)



Port B (PB5)
Port E (PE1*2)
Port G (PG3 to PG5*1, *2, *3)



Port E (PE2)



Note 1: Products in the 64-pin LQFP do not have these pins.
Note 2: Products in the 80-pin LQFP do not have these pins.
Note 3: Products in the 100-pin LQFP do not have these pins.
Note 4: When reading the port register (PORT), ensure that the corresponding bits in the ICR register are 1. If the PORT register is read while the setting of bits in the ICR register is 0, values read from the corresponding bits are undefined.

Figure 15.2 I/O Port Configuration (2)

15.6 Usage Notes

15.6.1 Setting the Input Buffer Control Register (PORTn.ICR)

Changes to PORTn.ICR settings can lead to the generation of internal edges, depending on the setting and the pin states at the time it is made. This may lead to operation that was not intended. Change the setting of a PORTn.ICR while the input signal from the pins is fixed to the high level or, if a peripheral function has been assigned to a pin, while the input function is disabled.
If a PORTn.ICR setting enables an input buffer, and several input functions have been allocated to the corresponding pin, the pin state is reflected in the values of all of the input signals. Thus, even for input functions that are not in use, attention must be paid to the settings of the corresponding peripheral modules.
If a pin is being used as an output pin, the output value is taken in as the pin state when the input buffer is enabled by a PORTn.ICR setting. For pins being used as output pins, disable the input buffer by setting the corresponding bits in the given PORTn.ICR.

15.6.2 Setting the Port Function Register

Each port function register controls an I/O port. When setting input or output functions for individual pins, select a pin for the input or output and then enable or disable the input or output function.
If the levels for a pin before and after it has been switched to operate as an input differ from each other, an internal edge is generated. This may lead to operation that was not intended. To avoid this, follow the procedure below when switching a pin to input operation.

1. Disable the input in the peripheral module settings that correspond to functions of the pin to be switched.
2. Make the port function register setting to select input operation for the pin.
3. Enable the input in the peripheral module settings that correspond to functions of the pin to be switched

If the settings for a pin before and after it has been switched to operate as an output differ from each other, an internal edge is output. This may lead to operation that was not intended. To avoid this, follow the procedure below when switching a pin to output operation.

1. Disable the output in the peripheral module settings that correspond to functions of the pin to be switched.
2. Make the port function register setting to select output operation for the pin.
3. Enable the output in the peripheral module settings that correspond to functions of the pin to be switched.

A single pin function may correspond to a pin selection bit for changing a pin for the input or output and a pin enable bit for enabling a pin function. In such cases, set the pin selection bit to select the pin for the input or output and then set the enable bit to enable the pin function.

15.6.3 Changing the Output Enable Settings

Pins are initially in the Hi-Z state because the output function of the port is initially disabled. If the output enable setting is changed, the port leaves the Hi-Z state and enters the output state (high or low); however, this may lead to generation of internal edges depending on the LSI internal state. To prevent edge generation, 0 or 1 should be previously set to the port data register (DR) using the procedure below.

Changing the pin state from Hi-Z to high output:

1. Set 1 (set the internal state of the LSI to high) to the port data register (DR) of the pins.
2. Select the output pins by setting the port function register.
3. Enable the pins for output.

Changing the pin state from Hi-Z to low output:

1. Set 0 (set the internal state of the LSI to low) to the port data register (DR) of the pins.
2. Select the output pins by setting the port function register.
3. Enable the pins for output.

15.6.4 Reading Port Registers (PORT)

Before reading the port registers (PORT) in ports 4, 5, and 6, enable the input buffer of the corresponding pins by setting the corresponding bits in PORTn.ICR to 1.
If the PORTn.PORT register is read with bits in the PORTn.ICR register set to 0, undefined values are read from the corresponding bits.

16. Multi-Function Timer Pulse Unit 3 (MTU3)

16.1 Overview

The RX62T Group has on-chip multi-function timer pulse unit 3 (MTU3), which comprises eight 16-bit timer channels. Table 16.1 shows the specifications of the MTU and Table 16.2 shows the function list of the MTU. Figure 16.1 and Figure 16.2 show block diagrams of the MTU.

Table 16.1 Specifications of MTU

Item	Description
Pulse input/output	24 lines max.
Pulse input	3 lines
Count clock	Six to eight clocks for each channel (four clocks for MTU5)
Operating frequency	8 to 100 MHz
Available operations	[MTU0 to MTU4, MTU6, and MTU7] • Waveform output on compare match • Input capture function • Counter-clearing operation • Simultaneous writing to multiple timer counters (TCNT) • Simultaneous clearing on compare match or input capture • Simultaneous input and output to registers in synchronization with counter operations • Up to 12-phase PWM output in combination with synchronous operation
	[MTU0, MTU3, MTU4, MTU6, and MTU7] • Buffer operation specifiable
	[MTU3, MTU4, MTU6, and MTU7] • Through interlocked operation of MTU3, MTU4, MTU6, and MTU7, output of positive and negative signals in six phases (for a total of 12 phases) in complementary-PWM and reset-PWM operation • In complementary PWM mode, transfer of values from buffer registers to temporary registers on peaks and troughs of the timer-counter values or writing to the buffer registers (MTU4.TGRD and MTU7.TGRD) • Double-buffering selectable in complementary PWM mode
	[MTU3 and MTU4] • Through interlocking with MTU0, a mode for driving AC synchronous motors (brushless DC motors) by using complementary PWM output and reset PWM output is settable and allows the selection of two types of waveform output (chopping or level)
	[MTU1 and MTU2] • Independently specifiable phase-counting mode • Capable of cascade-connected operation
	[MTU5] • Capable of operation as a dead-time compensation counter
Interrupt-skipping function in complementary PWM mode	• In complementary PWM mode, interrupts on crests and troughs of counter values and triggers to start conversion by the A/D converter can be skipped
Interrupt sources	38 sources
Buffer operation	Automatic transfer of register data (transfer from the buffer register to the timer register)
Trigger generation	A/D converter start triggers can be generated
	A/D converter start request delaying function enables A/D converter to be started with any desired timing and to be synchronized with PWM output
Power reduction	Module stop mode can be set.

Table 16.2 MTU Functions (1 / 3)

Item		MTU0	MTU1	MTU2	MTU3	MTU4	MTU5	MTU6	MTU7
Count clock		ICLK/1 ICLK/4 ICLK/16 ICLK/64 MTCLKA MTCLKB MTCLKC MTCLKD	ICLK/1 ICLK/4 ICLK/16 ICLK/64 ICLK/256 MTCLKA MTCLKB	ICLK/1 ICLK/4 ICLK/16 ICLK/64 ICLK/1024 MTCLKA MTCLKB MTCLKC	ICLK/1 ICLK/4 ICLK/16 ICLK/64 ICLK/256 ICLK/1024 MTCLKA MTCLKB	ICLK/1 ICLK/4 ICLK/16 ICLK/64 ICLK/256 ICLK/1024 MTCLKA MTCLKB	ICLK/1 ICLK/4 ICLK/16 ICLK/64	ICLK/1 ICLK/4 ICLK/16 ICLK/64 ICLK/256 ICLK/1024	ICLK/1 ICLK/4 ICLK/16 ICLK/64 ICLK/256 ICLK/1024
General registers (TGR)		TGRA TGRB TGRE	TGRA TGRB	TGRA TGRB	TGRA TGRB	TGRA TGRB	TGRU TGRV TGRW	TGRA TGRB	TGRA TGRB
General registers/ buffer registers		TGRC TGRD TGRF	—	—	TGRC TGRD TGRE	TGRC TGRD TGRE TGRF	—	TGRC TGRD TGRE	TGRC TGRD TGRE TGRF
I/O pins		MTIOC0A MTIOC0B MTIOC0C MTIOC0D	MTIOC1A MTIOC1B	MTIOC2A MTIOC2B	MTIOC3A MTIOC3B MTIOC3C MTIOC3D	MTIOC4A MTIOC4B MTIOC4C MTIOC4D	Input pins MTIC5U MTIC5V MTIC5W	MTIOC6A MTIOC6B MTIOC6C MTIOC6D	MTIOC7A MTIOC7B MTIOC7C MTIOC7D
Counter clear function		TGR compare match or input capture	TGR compare match or input capture	TGR compare match or input capture	TGR compare match or input capture	TGR compare match or input capture	TGR compare match or input capture	TGR compare match or input capture	TGR compare match or input capture
Compare match output	Low output	√	√	√	√	√	—	√	√
	High output	√	√	√	√	√	—	√	√
	Toggle output	√	√	√	√	√	—	√	√
Input capture function		√	√	√	√	√	√	√	√
Synchronous operation		√	√	√	√	√	—	√	√
PWM mode 1		√	√	√	√	√	—	√	√
PWM mode 2		√	√	√	—	—	—	—	—
Complementary PWM mode		—	—	—	√	√	—	√	√
Reset-synchronized PWM mode		—	—	—	√	√	—	√	√
AC synchronous motor drive mode		√	—	—	√	√	—	—	—
Phase counting mode		—	√	√	—	—	—	—	—
Buffer operation		√	—	—	√	√	—	√	√
Dead time compensation counter function		—	—	—	—	—	√	—	—

Table 16.2 MTU Functions (2 / 3)

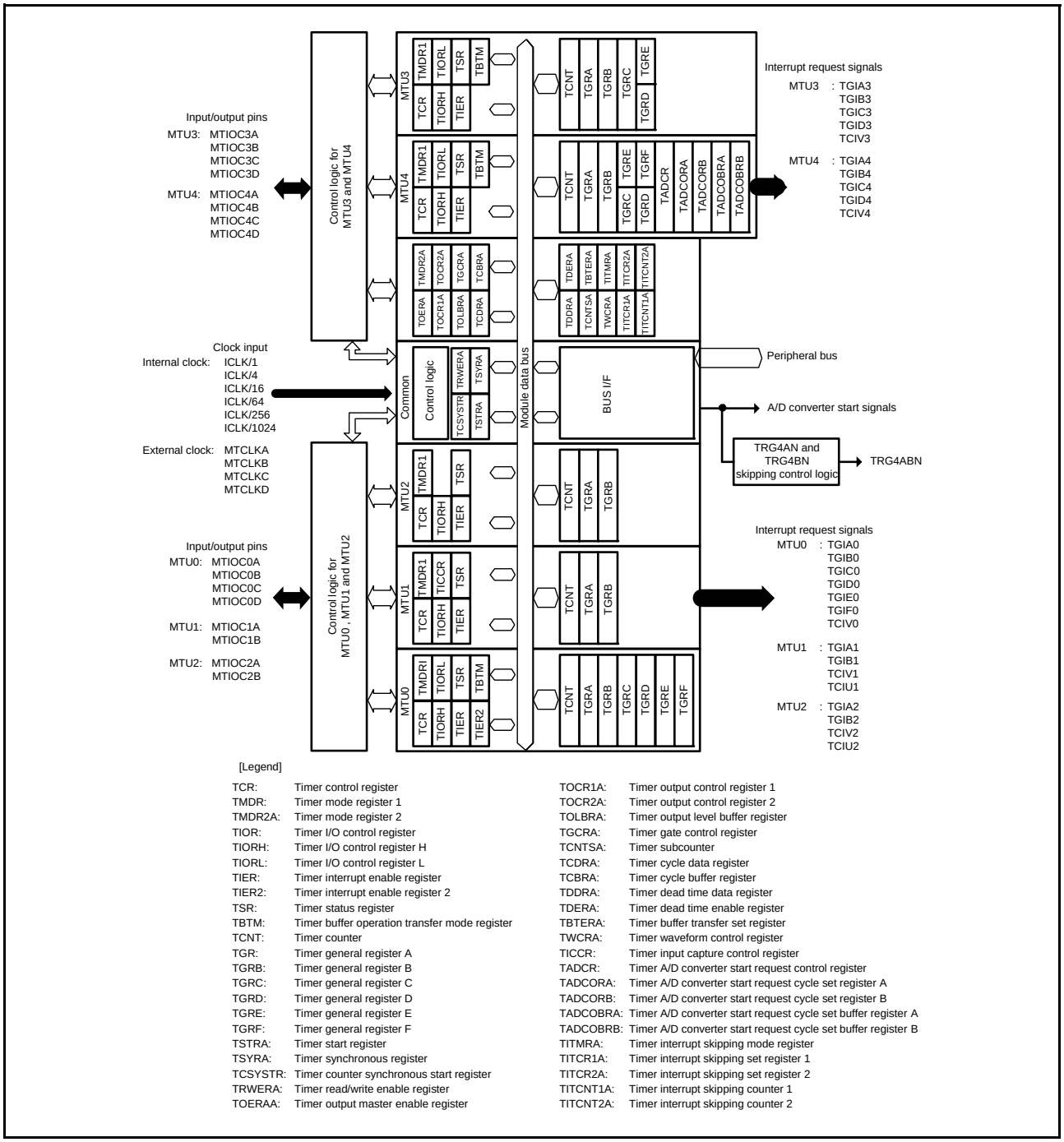
Item	MTU0	MTU1	MTU2	MTU3	MTU4	MTU5	MTU6	MTU7
Interrupt sources	7 sources • Compare match or input capture A • Compare match or input capture B • Compare match or input capture C • Compare match or input capture D • Compare match 0E • Compare match F • Overflow	4 sources • Compare match or input capture A • Compare match or input capture B • Overflow • Underflow	4 sources • Compare match or input capture A • Compare match or input capture B • Overflow • Underflow	5 sources • Compare match or input capture A • Compare match or input capture B • Compare match or input capture C • Compare match or input capture D • Overflow	5 sources • Compare match or input capture A • Compare match or input capture B • Compare match or input capture C • Compare match or input capture D • Overflow or underflow (only in complementary PWM mode)	3 sources • Compare match or input capture U • Compare match or input capture V • Compare match or input capture W	5 sources • Compare match or input capture A • Compare match or input capture B • Compare match or input capture C • Compare match or input capture D • Overflow	5 sources • Compare match or input capture A • Compare match or input capture B • Compare match or input capture C • Compare match or input capture D • Overflow or underflow (only in complementary PWM mode)
DTC activation	TGR compare match or input capture	TGR compare match or input capture	TGR compare match or input capture	TGR compare match or input capture	TGR compare match or input capture • Overflow or underflow (only in complementary PWM mode)	TGR compare match or input capture	TGR compare match or input capture	TGR compare match or input capture • Overflow or underflow (only in complementary PWM mode)
A/D converter start trigger	TGRA compare match or input capture TGRE compare match	TGRA compare match or input capture	TGRA compare match or input capture	TGRA compare match or input capture	TGRA compare match or input capture TCNT underflow (trough) in complementary PWM mode	—	TGRA compare match or input capture	TGRA compare match or input capture TCNT underflow (trough) in complementary PWM mode

Table 16.2 MTU Functions (3 / 3)

Item	MTU0	MTU1	MTU2	MTU3	MTU4	MTU5	MTU6	MTU7
A/D converter start request delaying function	—	—	—	—	• A/D converter start request at a match between TADCORA and TCNT • A/D converter start request at a match between TADCORB and TCNT	—	—	• A/D converter start request at a match between TADCORA and TCNT • A/D converter start request at a match between TADCORB and TCNT
Interrupt skipping function 1	—	—	—	• Skips TGRA compare match interrupts	• Skips TCIV interrupts	—	• Skips TGRA compare match interrupts	• Skips TCIV interrupts
Interrupt skipping function 2	—	—	—	—	• Skips interrupts according to the count of compare matches between TADCORA and TCNT and TADCORB and TCNT	—	—	• Skips interrupts according to the count of compare matches between TADCORA and TCNT and TADCORB and TCNT
Module stop function	MSTPCRA.MSTPA9*1							

√: Possible —: Not possible

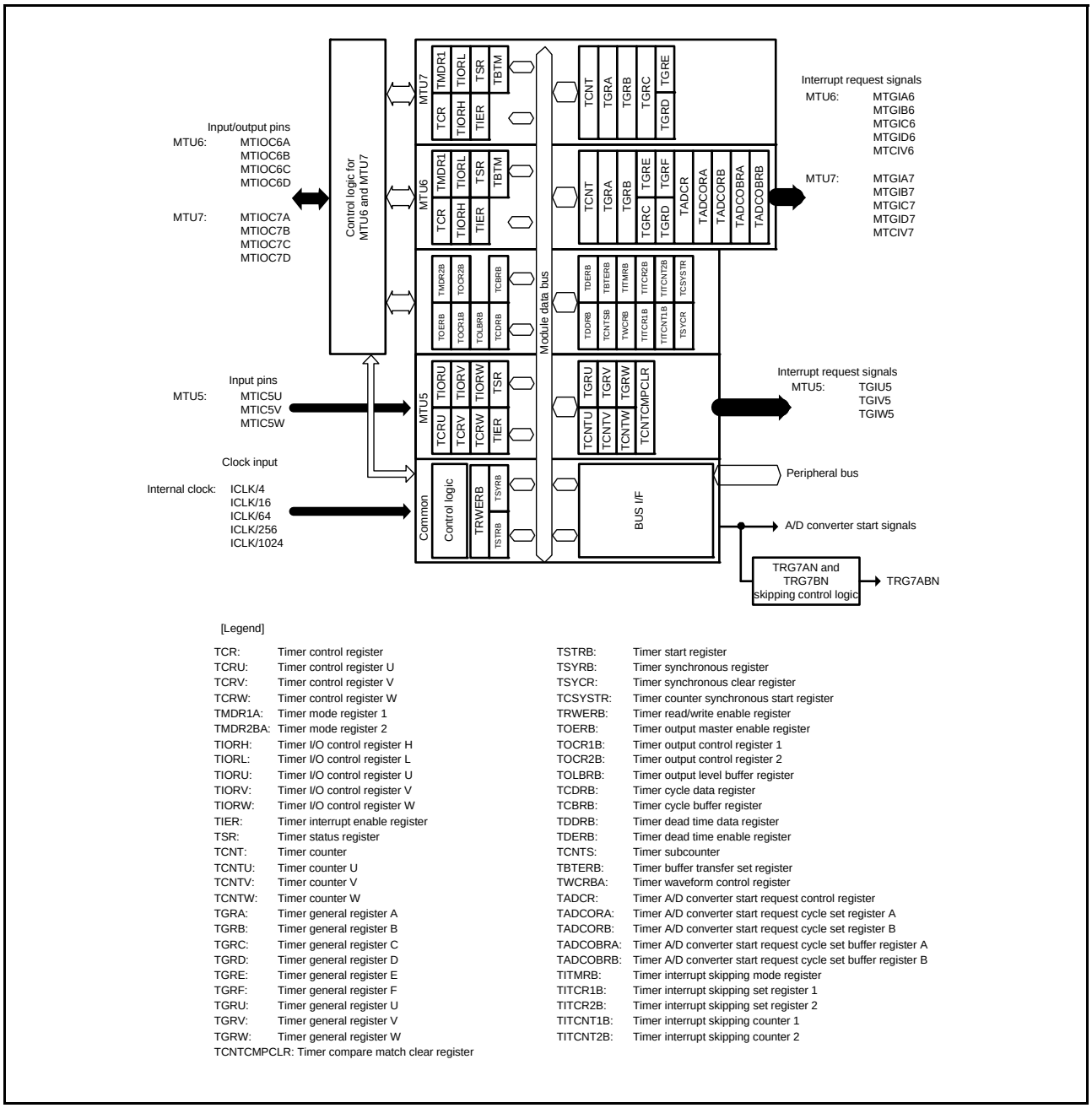
Note 1. For details on the module stop function, see section 9, Low Power Consumption.



[Legend]

TCR:	Timer control register	TOCR1A:	Timer output control register 1
TMDR:	Timer mode register 1	TOCR2A:	Timer output control register 2
TMDR2A:	Timer mode register 2	TOLBRA:	Timer output level buffer register
TIOR:	Timer I/O control register	TGCRA:	Timer gate control register
TIORH:	Timer I/O control register H	TCNTSA:	Timer subcounter
TIORL:	Timer I/O control register L	TCDRA:	Timer cycle data register
TIER:	Timer interrupt enable register	TCBRA:	Timer cycle buffer register
TIER2:	Timer interrupt enable register 2	TDDRA:	Timer dead time data register
TSR:	Timer status register	TDERA:	Timer dead time enable register
TBTM:	Timer buffer operation transfer mode register	TBTERA:	Timer buffer transfer set register
TCNT:	Timer counter	TWCRA:	Timer waveform control register
TGR:	Timer general register A	TICCR:	Timer input capture control register
TGRB:	Timer general register B	TADCR:	Timer A/D converter start request control register
TGRC:	Timer general register C	TADCORA:	Timer A/D converter start request cycle set register A
TGRD:	Timer general register D	TADCORB:	Timer A/D converter start request cycle set register B
TGRE:	Timer general register E	TADCOBRA:	Timer A/D converter start request cycle set buffer register A
TGRF:	Timer general register F	TADCOBRB:	Timer A/D converter start request cycle set buffer register B
TSTRA:	Timer start register	TITMRA:	Timer interrupt skipping mode register
TSYRA:	Timer synchronous register	TITCR1A:	Timer interrupt skipping set register 1
TCSYSTR:	Timer counter synchronous start register	TITCR2A:	Timer interrupt skipping set register 2
TRWERA:	Timer read/write enable register	TITCNT1A:	Timer interrupt skipping counter 1
TOERAA:	Timer output master enable register	TITCNT2A:	Timer interrupt skipping counter 2

Figure 16.1 Block Diagram of MTU (MTU0 to MTU4)



[Legend]

TCR:	Timer control register	TSTRB:	Timer start register
TCRU:	Timer control register U	TSYRB:	Timer synchronous register
TCRV:	Timer control register V	TSYCR:	Timer synchronous clear register
TCRW:	Timer control register W	TCSYSTR:	Timer counter synchronous start register
TMDR1A:	Timer mode register 1	TRWERB:	Timer read/write enable register
TMDR2BA:	Timer mode register 2	TOERB:	Timer output master enable register
TIORH:	Timer I/O control register H	TOCR1B:	Timer output control register 1
TIORL:	Timer I/O control register L	TOCR2B:	Timer output control register 2
TIORU:	Timer I/O control register U	TOLBRB:	Timer output level buffer register
TIORV:	Timer I/O control register V	TCDRB:	Timer cycle data register
TIORW:	Timer I/O control register W	TCBRB:	Timer cycle buffer register
TIER:	Timer interrupt enable register	TDDRB:	Timer dead time data register
TSR:	Timer status register	TDERB:	Timer dead time enable register
TCNT:	Timer counter	TCNTS:	Timer subcounter
TCNTU:	Timer counter U	TBTERB:	Timer buffer transfer set register
TCNTV:	Timer counter V	TWCRBA:	Timer waveform control register
TCNTW:	Timer counter W	TADCR:	Timer A/D converter start request control register
TGRA:	Timer general register A	TADCORA:	Timer A/D converter start request cycle set register A
TGRB:	Timer general register B	TADCORB:	Timer A/D converter start request cycle set register B
TGRC:	Timer general register C	TADCOBRA:	Timer A/D converter start request cycle set buffer register A
TGRD:	Timer general register D	TADCOBRB:	Timer A/D converter start request cycle set buffer register B
TGRE:	Timer general register E	TITMRB:	Timer interrupt skipping mode register
TGRF:	Timer general register F	TITCR1B:	Timer interrupt skipping set register 1
TGRU:	Timer general register U	TITCR2B:	Timer interrupt skipping set register 2
TGRV:	Timer general register V	TITCNT1B:	Timer interrupt skipping counter 1
TGRW:	Timer general register W	TITCNT2B:	Timer interrupt skipping counter 2

TCNTCMPCLR: Timer compare match clear register

Figure 16.2 Block Diagram of MTU (MTU5 to MTU7)

Table 16.3 shows the pin configuration of the MTU.

Table 16.3 Pin Configuration

Channel	Pin Name	I/O	Function
MTU	MTCLKA	Input	External clock A input pin (MTU1 phase counting mode A phase input)
	MTCLKB	Input	External clock B input pin (MTU1 phase counting mode B phase input)
	MTCLKC	Input	External clock C input pin (MTU1 phase counting mode A phase input)
	MTCLKD	Input	External clock D input pin (MTU2 phase counting mode B phase input)
MTU0	MTIOC0A	I/O	MTU0 TGRA input capture input/output compare output/PWM output pin
	MTIOC0B	I/O	MTU0 TGRB input capture input/output compare output/PWM output pin
	MTIOC0C	I/O	MTU0 TGRC input capture input/output compare output/PWM output pin
	MTIOC0D	I/O	MTU0 TGRD input capture input/output compare output/PWM output pin
MTU1	MTIOC1A	I/O	MTU1 TGRA input capture input/output compare output/PWM output pin
	MTIOC1B	I/O	MTU1 TGRB input capture input/output compare output/PWM output pin
MTU2	MTIOC2A	I/O	MTU2 TGRA input capture input/output compare output/PWM output pin
	MTIOC2B	I/O	MTU2 TGRB input capture input/output compare output/PWM output pin
MTU3	MTIOC3A	I/O	MTU3 TGRA input capture input/output compare output/PWM output pin
	MTIOC3B	I/O	MTU3 TGRB input capture input/output compare output/PWM output pin
	MTIOC3C	I/O	MTU3 TGRC input capture input/output compare output/PWM output pin
	MTIOC3D	I/O	MTU3 TGRD input capture input/output compare output/PWM output pin
MTU4	MTIOC4A	I/O	MTU4 TGRA input capture input/output compare output/PWM output pin
	MTIOC4B	I/O	MTU4 TGRB input capture input/output compare output/PWM output pin
	MTIOC4C	I/O	MTU4 TGRC input capture input/output compare output/PWM output pin
	MTIOC4D	I/O	MTU4 TGRD input capture input/output compare output/PWM output pin
MTU5	MTIC5U	Input	MTU5 TGRU input capture input/external pulse input pin
	MTIC5V	Input	MTU5 TGRV input capture input/external pulse input pin
	MTIC5W	Input	MTU5 TGRW input capture input/external pulse input pin
MTU6	MTIOC6A	I/O	MTU6 TGRA input capture input/output compare output/PWM output pin
	MTIOC6B	I/O	MTU6 TGRB input capture input/output compare output/PWM output pin
	MTIOC6C	I/O	MTU6 TGRC input capture input/output compare output/PWM output pin
	MTIOC6D	I/O	MTU6 TGRD input capture input/output compare output/PWM output pin
MTU7	MTIOC7A	I/O	MTU7 TGRA input capture input/output compare output/PWM output pin
	MTIOC7B	I/O	MTU7 TGRB input capture input/output compare output/PWM output pin
	MTIOC7C	I/O	MTU7 TGRC input capture input/output compare output/PWM output pin
	MTIOC7D	I/O	MTU7 TGRD input capture input/output compare output/PWM output pin

16.2 Register Descriptions

Table 16.4 lists the registers of the MTU3.

Table 16.4 Registers of MTU3 (1 / 6)

Channel	Register Name	Symbol	Value after Reset	Address	Access Size
MTU0	Timer control register	TCR	00h	000C 1300h	8, 16, 32
	Timer mode register 1	TMDR1	00h	000C 1301h	8
	Timer I/O control register H	TIORH	00h	000C 1302h	8, 16
	Timer I/O control register L	TIORL	00h	000C 1303h	8
	Timer interrupt enable register	TIER	00h	000C 1304h	8, 16, 32
	Timer status register	TSR	C0h	000C 1305h	8
	Timer counter	TCNT	0000h	000C 1306h	16
	Timer general register A	TGRA	FFFFh	000C 1308h	16, 32
	Timer general register B	TGRB	FFFFh	000C 130Ah	16
	Timer general register C	TGRC	FFFFh	000C 130Ch	16, 32
	Timer general register D	TGRD	FFFFh	000C 130Eh	16
	Timer general register E	TGRE	FFFFh	000C 1320h	16, 32
	Timer general register F	TGRF	FFFFh	000C 1322h	16
	Timer interrupt enable register 2	TIER2	00h	000C 1324h	8, 16
	Timer status register 2	TSR2	C0h	000C 1325h	8
	Timer buffer operation transfer mode register	TBTM	00h	000C 1326h	8
MTU1	Timer control register	TCR	00h	000C 1380h	8, 16
	Timer mode register 1	TMDR1	00h	000C 1381h	8
	Timer I/O control register	TIOR	00h	000C 1382h	8
	Timer interrupt enable register	TIER	00h	000C 1384h	8, 16, 32
	Timer status register	TSR	C0h	000C 1385h	8
	Timer counter	TCNT	0000h	000C 1386h	16
	Timer general register A	TGRA	FFFFh	000C 1388h	16, 32
	Timer general register B	TGRB	FFFFh	000C 138Ah	16
	Timer input capture control register	TICCR	00h	000C 1390h	8
MTU2	Timer control register	TCR	00h	000C 1400h	8, 16
	Timer mode register 1	TMDR1	00h	000C 1401h	8
	Timer I/O control register	TIOR	00h	000C 1402h	8
	Timer interrupt enable register	TIER	00h	000C 1404h	8, 16, 32
	Timer status register	TSR	C0h	000C 1405h	8
	Timer counter	TCNT	0000h	000C 1406h	16
	Timer general register A	TGRA	FFFFh	000C 1408h	16, 32
	Timer general register B	TGRB	FFFFh	000C 140Ah	16

Table 16.4 Registers of MTU3 (2 / 6)

Channel	Register Name	Symbol	Value after Reset	Address	Access Size
MTU3	Timer control register	TCR	00h	000C 1200h	8, 16, 32
	Timer mode register 1	TMDR1	00h	000C 1202h	8, 16
	Timer I/O control register H	TIORH	00h	000C 1204h	8, 16, 32
	Timer I/O control register L	TIORL	00h	000C 1205h	8
	Timer interrupt enable register	TIER	00h	000C 1208h	8, 16
	Timer counter	TCNT	0000h	000C 1210h	16, 32
	Timer general register A	TGRA	FFFFh	000C 1218h	16, 32
	Timer general register B	TGRB	FFFFh	000C 121Ah	16
	Timer general register C	TGRC	FFFFh	000C 1224h	16, 32
	Timer general register D	TGRD	FFFFh	000C 1226h	16
	Timer general register E	TGRE	FFFFh	000C 1272h	16
	Timer status register	TSR	C0h	000C 122Ch	8, 16
	Timer buffer operation transfer mode register	TBTM	00h	000C 1238h	8, 16
MTU4	Timer control register	TCR	00h	000C 1201h	8
	Timer mode register 1	TMDR1	00h	000C 1203h	8
	Timer I/O control register H	TIORH	00h	000C 1206h	8, 16
	Timer I/O control register L	TIORL	00h	000C 1207h	8
	Timer interrupt enable register	TIER	00h	000C 1209h	8
	Timer counter	TCNT	0000h	000C 1212h	16
	Timer general register A	TGRA	FFFFh	000C 121Ch	16, 32
	Timer general register B	TGRB	FFFFh	000C 121Eh	16
	Timer general register C	TGRC	FFFFh	000C 1228h	16, 32
	Timer general register D	TGRD	FFFFh	000C 122Ah	16
	Timer general register E	TGRE	FFFFh	000C 1274h	16
	Timer general register F	TGRF	FFFFh	000C 1276h	16
	Timer status register	TSR	C0h	000C 122Dh	8
	Timer buffer operation transfer mode register	TBTM	00h	000C 1239h	8
MTU4	Timer A/D converter start request control register	TADCR	0000h	000C 1240h	16
	Timer A/D converter start request cycle set register A	TADCORA	FFFFh	000C 1244h	16, 32
	Timer A/D converter start request cycle set register B	TADCORB	FFFFh	000C 1246h	16
	Timer A/D converter start request cycle set buffer register A	TADCOBRA	FFFFh	000C 1248h	16, 32
	Timer A/D converter start request cycle set buffer register B	TADCOBRB	FFFFh	000C 124Ah	16

Table 16.4 Registers of MTU3 (3 / 6)

Channel	Register Name	Symbol	Value after Reset	Address	Access Size
MTU5	Timer counter U	TCNTU	0000h	000C 1C80h	16, 32
	Timer general register U	TGRU	FFFFh	000C 1C82h	16
	Timer control register U	TCRU	00h	000C 1C84h	8
	Timer I/O control register U	TIORU	00h	000C 1C86h	8
	Timer counter V	TCNTV	0000h	000C 1C90h	16, 32
	Timer general register V	TGRV	FFFFh	000C 1C92h	16
	Timer control register V	TCRV	00h	000C 1C94h	8
	Timer I/O control register V	TIORV	00h	000C 1C96h	8
	Timer counter W	TCNTW	0000h	000C 1CA0h	16, 32
	Timer general register W	TGRW	FFFFh	000C 1CA2h	16
	Timer control register W	TCRW	00h	000C 1CA4h	8
	Timer I/O control register W	TIORW	00h	000C 1CA6h	8
	Timer status register	TSR	00h	000C 1CB0h	8
	Timer interrupt enable register	TIER	00h	000C 1CB2h	8
	Timer start register	TSTR	00h	000C 1CB4h	8
	Timer compare match clear register	TCNTCMPCLR	00h	000C 1CB6h	8
MTU6	Timer control register	TCR	00h	000C 1A00h	8, 16, 32
	Timer mode register 1	TMDR1	00h	000C 1A02h	8, 16
	Timer I/O control register H	TIORH	00h	000C 1A04h	8, 16, 32
	Timer I/O control register L	TIORL	00h	000C 1A05h	8
	Timer interrupt enable register	TIER	00h	000C 1A08h	8, 16
	Timer counter	TCNT	0000h	000C 1A10h	16, 32
	Timer general register A	TGRA	FFFFh	000C 1A18h	16, 32
	Timer general register B	TGRB	FFFFh	000C 1A1Ah	16
	Timer general register C	TGRC	FFFFh	000C 1A24h	16, 32
	Timer general register D	TGRD	FFFFh	000C 1A26h	16
	Timer general register E	TGRE	FFFFh	000C 1A72h	16
	Timer synchronous clear register	TSYCR	00h	000C 1A50h	8
	Timer status register	TSR	C0h	000C 1A2Ch	8, 16
	Timer buffer operation transfer mode register	TBTM	00h	000C 1A38h	8, 16

Table 16.4 Registers of MTU3 (4 / 6)

Channel	Register Name	Symbol	Value after Reset	Address	Access Size
MTU7	Timer control register	TCR	00h	000C 1A01h	8
	Timer mode register 1	TMDR1	00h	000C 1A03h	8
	Timer I/O control register H	TIORH	00h	000C 1A06h	8, 16
	Timer I/O control register L	TIORL	00h	000C 1A07h	8
	Timer interrupt enable register	TIER	00h	000C 1A09h	8
	Timer counter	TCNT	0000h	000C 1A12h	16
	Timer general register A	TGRA	FFFFh	000C 1A1Ch	16, 32
	Timer general register B	TGRB	FFFFh	000C 1A1Eh	16
	Timer general register C	TGRC	FFFFh	000C 1A28h	16, 32
	Timer general register D	TGRD	FFFFh	000C 1A2Ah	16
	Timer general register E	TGRE	FFFFh	000C 1A74h	16
	Timer general register F	TGRF	FFFFh	000C 1A76h	16
	Timer status register	TSR	C0h	000C 1A2Dh	8
	Timer buffer operation transfer mode register	TBTM	00h	000C 1A39h	8
	Timer A/D converter start request control register	TADCR	0000h	000C 1A40h	16
	Timer A/D converter start request cycle set register A	TADCORA	FFFFh	000C 1A44h	16, 32
	Timer A/D converter start request cycle set register B	TADCORB	FFFFh	000C 1A46h	16
	Timer A/D converter start request cycle set buffer register A	TADCOBRA	FFFFh	000C 1A48h	16, 32
	Timer A/D converter start request cycle set buffer register B	TADCOBRB	FFFFh	000C 1A4Ah	16
MTU3, MTU4 common	Timer output master enable register A	TOERA	C0h	000C 120Ah	8
MTU6, MTU7 common	Timer output master enable register B	TOERB	C0h	000C 1A0Ah	8
MTU3, MTU4 common	Timer gate control register A	TGCRA	80h	000C 120Dh	8
MTU3, MTU4 common	Timer output control register 1A	TOCR1A	00h	000C 120Eh	8, 16
MTU6, MTU7 common	Timer output control register 1B	TOCR1B	00h	000C 1A0Eh	8, 16
MTU3, MTU4 common	Timer output control register 2A	TOCR2A	00h	000C 120Fh	8
MTU6, MTU7 common	Timer output control register 2B	TOCR2B	00h	000C 1A0Fh	8
MTU3, MTU4 common	Timer cycle data register A	TCDRA	FFFFh	000C 1214h	16, 32
MTU6, MTU7 common	Timer cycle data register B	TCDRB	FFFFh	000C 1A14h	16, 32
MTU3, MTU4 common	Timer dead time data register A	TDDRA	FFFFh	000C 1216h	16
MTU6, MTU7 common	Timer dead time data register B	TDDRB	FFFFh	000C 1A16h	16
MTU3, MTU4 common	Timer dead time enable register A	TDERA	01h	000C 1234h	8
MTU6, MTU7 common	Timer dead time enable register B	TDERB	01h	000C 1A34h	8

Table 16.4 Registers of MTU3 (5 / 6)

Channel	Register Name	Symbol	Value after Reset	Address	Access Size
MTU3, MTU4 common	Timer subcounter A	TCNTSA	0000h	000C 1220h	16, 32
MTU6, MTU7 common	Timer subcounter B	TCNTSB	0000h	000C 1A20h	16, 32
MTU3, MTU4 common	Timer cycle buffer register A	TCBRA	FFFFh	000C 1222h	16
MTU6, MTU7 common	Timer cycle buffer register B	TCBRB	FFFFh	000C 1A22h	16
MTU3, MTU4 common	Timer interrupt skipping set register 1A	TITCR1A	00h	000C 1230h	8, 16
MTU6, MTU7 common	Timer interrupt skipping set register 1B	TITCR1B	00h	000C 1A30h	8, 16
MTU3, MTU4 common	Timer interrupt skipping set register 2A	TITCR2A	00h	000C 123Bh	8
MTU6, MTU7 common	Timer interrupt skipping set register 2B	TITCR2B	00h	000C 1A3Bh	8
MTU3, MTU4 common	Timer interrupt skipping counter 1A	TITCNT1A	00h	000C 1231h	8
MTU6, MTU7 common	Timer interrupt skipping counter 1B	TITCNT1B	00h	000C 1A31h	8
MTU3, MTU4 common	Timer interrupt skipping counter 2A	TITCNT2A	00h	000C 123Ch	8
MTU6, MTU7 common	Timer interrupt skipping counter 2B	TITCNT2B	00h	000C 1A3Ch	8
MTU3, MTU4 common	Timer buffer transfer set register A	TBTERA	00h	000C 1232h	8
MTU6, MTU7 common	Timer buffer transfer set register B	TBTERB	00h	000C 1A32h	8
MTU3, MTU4 common	Timer output level buffer register A	TOLBRA	00h	000C 1236h	8
MTU6, MTU7 common	Timer output level buffer register B	TOLBRB	00h	000C 1A36h	8
MTU3, MTU4 common	Timer mode register 2A	TMDR2A	00h	000C 1270h	8
MTU6, MTU7 common	Timer mode register 2B	TMDR2B	00h	000C 1A70h	8
MTU3, MTU4 common	Timer interrupt skipping mode register A	TITMRA	00h	000C 123Ah	8
MTU6, MTU7 common	Timer interrupt skipping mode register B	TITMRB	00h	000C 1A3Ah	8
MTU3, MTU4 common	Timer waveform control register A	TWCRA	00h	000C 1260h	8
MTU6, MTU7 common	Timer waveform control register B	TWCRB	00h	000C 1A60h	8
MTU0 to MTU4 common	Timer start register A	TSTRA	00h	000C 1280h	8, 16
MTU6, MTU7 common	Timer start register B	TSTRB	00h	000C 1A80h	8, 16
MTU0 to MTU4 common	Timer synchronous register A	TSYRA	00h	000C 1281h	8
MTU6, MTU7 common	Timer synchronous register B	TSYRB	00h	000C 1A81h	8
MTU0 to MTU7 Common	Timer counter synchronous start register	TCSYSTR	00h	000C 1282h	8

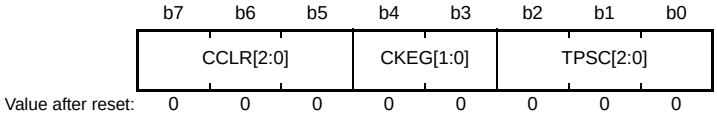
Table 16.4 Registers of MTU3 (6 / 6)

Channel	Register Name	Symbol	Value after Reset	Address	Access Size
MTU3, MTU4 common	Timer read/write enable register A	TRWERA	01h	000C 1284h	8
MTU6, MTU7 common	Timer read/write enable register B	TRWERB	01h	000C 1A84h	8

16.2.1 Timer Control Register (TCR)

- MTU0, MTU1, MTU2, MTU3, MTU4, MTU6, MTU7

Address: MTU0.TCR 000C 1300h, MTU1.TCR 000C 1380h, MTU2.TCR 000C 1400h, MTU3.TCR 000C 1200h, MTU4.TCR 000C 1201h, MTU6.TCR 000C 1A00h, MTU7.TCR 000C 1A01h



Bit	Symbol	Bit Name	Description	R/W
b2 to b0	TPSC[2:0]	Time Prescaler Select	See Table 16.7 to Table 16.10.	R/W
b4, b3	CKEG[1:0]	Clock Edge Select	b4 b3 0 0: Count at rising edge 0 1: Count at falling edge 1 x: Count at both edges	R/W
b7 to b5	CCLR[2:0]	Counter Clear Source Select	See Table 16.5 and Table 16.6.	R/W

x: Don't care

TCR controls the TCNT operation for each channel. The MTU has a total of ten TCR registers, one each for MTU 0 to MTU4, MTU6 and MTU7 and three (TCRU, TCRV, and TCRW) for MTU 5. TCR values should be specified only while TCNT operation is stopped.

TPSC[2:0] Bits (Time Prescaler Select)

These bits select the TCNT counter clock. The clock source can be selected independently for each channel. See Table 16.7 to Table 16.10 for details.

CKEG[1: 0] Bits (Clock Edge Select)

These bits select the input clock edge. When the input clock is counted at both edges, the input clock period is halved (e.g. ICLK/4 at both edges = ICLK/2 at rising edge). If phase counting mode is used on MTU1 and MTU2, the setting of these bits is ignored and the phase counting mode setting has priority. Internal clock edge selection is valid when the input clock is ICLK/4 or slower. When ICLK/1 or the overflow/underflow in another channel is selected for the input clock, a value can be written to these bits but counter operation compiles with the initial value.

CCLR[2:0] Bits (Counter Clear Source Select)

These bits select the TCNT counter clearing source. See Table 16.5 and Table 16.6 for details.

- MTU5

Address: MTU5.TCRU 000C 1C84h, MTU5.TCRV 000C 1C94h, MTU5.TCRW 000C 1CA4h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	TPSC[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1, b0	TPSC[1:0]	Time Prescaler Select	See Table 16.11.	R/W
b7 to b2	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W

TPSC[1:0] Bits (Time Prescaler Select)

These bits select the TCNT counter clock. See Table 16.11 for details.

Table 16.5 CCLR[2:0] (MTU0, MTU3, MTU4, MTU6, and MTU7)

	Bit 7	Bit 6	Bit 5	
Channel	CCLR2	CCLR1	CCLR0	Description
MTU0 MTU3 MTU4 MTU6 MTU7	0	0	0	TCNT clearing disabled
	0	0	1	TCNT cleared by TGRA compare match/input capture
	0	1	0	TCNT cleared by TGRB compare match/input capture
	0	1	1	TCNT cleared by counter clearing in another channel performing synchronous clearing/synchronous operation*1
	1	0	0	TCNT clearing disabled
	1	0	1	TCNT cleared by TGRC compare match/input capture*2
	1	1	0	TCNT cleared by TGRD compare match/input capture*2
	1	1	1	TCNT cleared by counter clearing in another channel performing synchronous clearing/synchronous operation*1

Note 1. Synchronous operation is selected by setting the TSYRA.SYNC or TSYRB.SYNC bit to 1.
Note 2. When TGRC or TGRD is used as a buffer register, TCNT is not cleared because the buffer register setting has priority and compare match/input capture does not occur.

Table 16.6 CCLR[2:0] (MTU1 and MTU2)

	Bit 7	Bit 6		
Channel	Reserved*2	CCLR1	CCLR0	Description
MTU1 MTU2	0	0	0	TCNT clearing disabled
	0	0	1	TCNT cleared by TGRA compare match/input capture
	0	1	0	TCNT cleared by TGRB compare match/input capture
	0	1	1	TCNT cleared by counter clearing in another channel performing synchronous clearing/synchronous operation*1

Note 1. Synchronous operation is selected by setting the TSYRA.SYNC and TSYRB.SYNC bits to 1.
Note 2. Bit 7 is reserved in MTU1 and MTU2. It is always read as 0. The write value is ignored.

Table 16.7 TPSC[2:0] (MTU0)

Channel	Bit 2 TPSC2	Bit 1 TPSC1	Bit 0 TPSC0	Description
MTU0	0	0	0	Internal clock: counts on ICLK/1
	0	0	1	Internal clock: counts on ICLK/4
	0	1	0	Internal clock: counts on ICLK/16
	0	1	1	Internal clock: counts on ICLK/64
	1	0	0	External clock: counts on MTCLKA pin input
	1	0	1	External clock: counts on MTCLKB pin input
	1	1	0	External clock: counts on MTCLKC pin input
	1	1	1	External clock: counts on MTCLKD pin input

Table 16.8 TPSC[2:0] (MTU1)

Channel	Bit 2 TPSC2	Bit 1 TPSC1	Bit 0 TPSC0	Description
MTU1	0	0	0	Internal clock: counts on ICLK/1
	0	0	1	Internal clock: counts on ICLK/4
	0	1	0	Internal clock: counts on ICLK/16
	0	1	1	Internal clock: counts on ICLK/64
	1	0	0	External clock: counts on MTCLKA pin input
	1	0	1	External clock: counts on MTCLKB pin input
	1	1	0	Internal clock: counts on ICLK/256
	1	1	1	Counts on MTU2.TCNT overflow/underflow

Note: • This setting is ignored when MTU1 is in phase counting mode.

Table 16.9 TPSC[2:0] (MTU2)

Channel	Bit 2 TPSC2	Bit 1 TPSC1	Bit 0 TPSC0	Description
MTU2	0	0	0	Internal clock: counts on ICLK/1
	0	0	1	Internal clock: counts on ICLK/4
	0	1	0	Internal clock: counts on ICLK/16
	0	1	1	Internal clock: counts on ICLK/64
	1	0	0	External clock: counts on MTCLKA pin input
	1	0	1	External clock: counts on MTCLKB pin input
	1	1	0	External clock: counts on MTCLKC pin input
	1	1	1	Internal clock: counts on ICLK/1024

Note: • This setting is ignored when MTU2 is in phase counting mode.

Table 16.10 TPSC[2:0] (MTU3, MTU4, MTU6 and MTU7)

	Bit 2	Bit 1	Bit 0	
Channel	**TPSC2**	**TPSC1**	**TPSC0**	**Description**
MTU3 MTU4 MTU6 MTU7	0	0	0	Internal clock: counts on ICLK/1
	0	0	1	Internal clock: counts on ICLK/4
	0	1	0	Internal clock: counts on ICLK/16
	0	1	1	Internal clock: counts on ICLK/64
	1	0	0	Internal clock: counts on ICLK/256
	1	0	1	Internal clock: counts on ICLK/1024
	1	1	0	External clock: counts on MTCLKA pin input*1
	1	1	1	External clock: counts on MTCLKB pin input*1

Note 1. This setting is not allowed in MTU6 and MTU7.

Table 16.11 TPSC[1:0] (MTU5)

	Bit 1	Bit 0	
Channel	**TPSC1**	**TPSC0**	**Description**
MTU5	0	0	Internal clock: counts on ICLK/1
	0	1	Internal clock: counts on ICLK/4
	1	0	Internal clock: counts on ICLK/16
	1	1	Internal clock: counts on ICLK/64

Note: • Bits 7 to 2 are reserved in MTU5. These bits are always read as 0. The write value should be 0.

16.2.2 Timer Mode Register 1 (TMDR1)

- MTU0.TMDR1

Address: MTU0.TMDR1 000C 1301h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	BFE	BFB	BFA	MD[3:0]			
Value after reset:	0	0	0	0	0	0	0	0

- MTU1.TMDR1, MTU2.TMDR1

Address: MTU1.TMDR1 000C 1381h, MTU2.TMDR1 000C 1401h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	MD[3:0]			
Value after reset:	0	0	0	0	0	0	0	0

- MTU3.TMDR1, MTU4.TMDR1, MTU6.TMDR1, MTU7.TMDR1

Address: MTU3.TMDR1 000C 1202h,MTU4.TMDR1 000C 1203h,
MTU6.TMDR1 000C 1A02h,MTU7.TMDR1 000C 1A03h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	BFB	BFA	MD[3:0]			
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b3 to b0	MD[3:0]	Mode Select	These bits specify the timer operating mode. See Table 16.12 for details.	R/W
b4	BFA	Buffer Operation A	0: TGRA and TGRC operate normally 1: TGRA and TGRC used together for buffer operation	R/W
b5	BFB	Buffer Operation B	0: TGRB and TGRD operate normally 1: TGRB and TGRD used together for buffer operation	R/W
b6	BFE	Buffer Operation E	0: MTU0.TGRE and MTU0.TGRF operate normally 1: MTU0.TGRE and MTU0.TGRF used together for buffer operation	R/W
b7	—	Reserved	This bit is always read as 0. The write value should be 0.	R/W

TMDR1 specifies the operating mode of each channel. The MTU3 has a total of seven TMDR1 registers, one each for MTU0 to MTU4, MTU6, and MTU7. TMDR1 values should be specified only while TCNT operation is stopped.

Table 16.12 Operating Mode Setting by MD[3:0] Bits

Bit 3	Bit 2	Bit 1	Bit 0	
MD3	MD2	MD1	MD0	Description
0	0	0	0	Normal operation
0	0	0	1	Setting prohibited
0	0	1	0	PWM mode 1
0	0	1	1	PWM mode 2*1
0	1	0	0	Phase counting mode 1*2
0	1	0	1	Phase counting mode 2*2
0	1	1	0	Phase counting mode 3*2
0	1	1	1	Phase counting mode 4*2
1	0	0	0	Reset-synchronized PWM mode *3
1	0	0	1	Setting prohibited
1	0	1	x	Setting prohibited
1	1	0	0	Setting prohibited
1	1	0	1	Complementary PWM mode 1 (transfer at crest) *3
1	1	1	0	Complementary PWM mode 2 (transfer at trough)*3
1	1	1	1	Complementary PWM mode 3 (transfer at crest and trough)*3

x: Don't care

Note 1. PWM mode 2 cannot be set for MTU3, MTU4, MTU6, and MTU7.

Note 2. Phase counting mode cannot be set for MTU0, MTU3, MTU4, MTU6, and MTU7.

Note 3. Reset-synchronized PWM mode and complementary PWM mode can only be set for MTU3 and MTU6.
When MTU3 or MTU6 is set to reset-synchronized PWM mode or complementary PWM mode, the settings of MTU4 and MTU7 become ineffective and automatically conform to the setting of MTU3 or MTU6, respectively. MTU4 and MTU7 should be set to the initial values (normal operation).
Reset-synchronized PWM mode and complementary PWM mode cannot be set for MTU0, MTU1, and MTU2.

BFA Bit (Buffer Operation A)

This bit specifies whether to operate TGRA in the normal way or to use TGRA and TGRC together for buffer operation. When TGRC is used as a buffer register, TGRC input capture/output compare does not take place.

In reset synchronized PWM mode or complementary PWM mode, buffer operation in MTU3 and MTU4 (or MTU6 and MTU7) depends on the settings in the BFA bit of MTU3.TMDR1 (MTU6.TMDR1). The BFA bit of MTU4.TMDR1 (MTU7.TMDR1) should be set to 0.

In MTU1 and MTU2, which have no TGRC, this bit is reserved. It is always read as 0. The write value should be 0.

BFB Bit (Buffer Operation B)

This bit specifies whether to operate TGRB in the normal way or to use TGRB and TGRD together for buffer operation. When TGRD is used as a buffer register, TGRD input capture/output compare does not take place.

In reset synchronized PWM mode or complementary PWM mode, buffer operation in MTU3 and MTU4 (or MTU6 and MTU7) depends on the settings in the BFB bit of MTU3.TMDR1 (MTU6.TMDR1). The BFB bit of MTU4.TMDR1 (MTU7.TMDR1) should be set to 0.

In MTU1 and MTU2, which have no TGRD, this bit is reserved. It is always read as 0. The write value should be 0.

BFE Bit (Buffer Operation E)

This bit specifies whether to operate MTU0.TGRE and MTU0.TGRF in the normal way or to use them together for buffer operation.

In MTU1 to MTU4, MTU6, and MTU7, this bit is reserved. It is always read as 0. The write value should be 0.

16.2.3 Timer Mode Registers 2 (TMDR2A and TMDR2B)

Address: TMDR2A 000C 1270h,TMDR2B 000C 1A70h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	DRS
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	DRS	Double Buffer Select	0: Double buffer function is disabled 1: Double buffer function is enabled	R/W
b7 to b1	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W

TMDR2 specifies the double buffer function in complementary PWM mode 3 (transfer at the crest and trough of the counter value). The MTU3 has two TMDR2 registers, one each for MTU3 (TMDR2A) and MTU6 (TMDR2B). TMDR2A and TMDR2B values should be specified only while TCNT operation is stopped.

DRS Bit (Double Buffer Select)

This bit enables or disables the double buffer function in complementary PWM mode.

16.2.4 Timer I/O Control Register (TIOR)

- MTU0.TIORH, MTU1.TIOR, MTU2.TIOR, MTU3.TIORH, MTU4.TIORH, MTU6.TIORH, MTU7.TIOR

Address: MTU0.TIORH 000C 1302h,MTU1.TIOR 000C 1382h,MTU2.TIOR 000C 1402h,
MTU3.TIORH 000C 1204h,MTU4.TIORH 000C 1206h,MTU6.TIORH 000C 1A04h,
MTU7.TIORH 000C 1A06h

	b7	b6	b5	b4	b3	b2	b1	b0
	IOB[3:0]				IOA[3:0]			
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b3 to b0	IOA[3:0]	I/O Control A	See the following tables. MTU0.TIORH: Table 16.25 MTU1.TIOR: Table 16.27 MTU2.TIOR: Table 16.28 MTU3.TIORH: Table 16.29 MTU4.TIORH: Table 16.31 MTU6.TIORH: Table 16.33 MTU7.TIORH: Table 16.35	R/W
b7 to b4	IOB[3:0]	I/O Control B	See the following tables. MTU0.TIORH: Table 16.13 MTU1.TIOR: Table 16.15 MTU2.TIOR: Table 16.16 MTU3.TIORH: Table 16.17 MTU4.TIORH: Table 16.19 MTU5.TIORH: Table 16.21 MTU6.TIORH: Table 16.23	R/W

- MTU0.TIORL, MTU3.TIORL, MTU4.TIORL, MTU6.TIORL, MTU7.TIORL

Address: MTU0.TIORL 000C 1303h, MTU3.TIORL 000C 1205h, MTU4.TIORL 000C 1207h, MTU6.TIORL 000C 1A05h, MTU7.TIORL 000C 1A07h

Bit	Symbol	Bit Name	Description	R/W
b3 to b0	IOC[3:0]	I/O Control C	See the following tables. MTU0.TIORL: Table 16.26 MTU3.TIORL: Table 16.30 MTU4.TIORL: Table 16.32 MTU6.TIORL: Table 16.34 MTU7.TIORL: Table 16.36	R/W
b7 to b4	IOD[3:0]	I/O Control D	See the following tables. MTU0.TIORL: Table 16.14 MTU3.TIORL: Table 16.18 MTU4.TIORL: Table 16.20 MTU6.TIORL: Table 16.22 MTU7.TIORL: Table 16.24	R/W

- MTU5.TIORU, MTU5.TIORV, MTU5.TIORW

Address: MTU5.TIORU 000C 1C86h, MTU5.TIORV 000C 1C96h, MTU5.TIORW 000C 1CA6h

Bit	Symbol	Bit Name	Description	R/W
b4 to b0	IOC[4:0]	I/O Control C	See the following table. MTU5.TIORU, MTU5.TIORV, MTU5.TIORW: Table 16.37	R/W
b7 to b5	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W

TIOR controls TGR. The MTU3 has a total of 15 TIOR registers, two each for MTU0, MTU3, MTU4, MTU6, and MTU7, one each for MTU1 and MTU2, and three (MTU5.TIORU/V/W) for MTU5.

Note that TIOR is affected by the TMDR1 setting.

The initial output specified by TIOR is valid when the counter is stopped (the CST bit in TSTRA and the CST bit in TSYRB are cleared to 0). Note also that, in PWM mode 2, the output at the point at which the counter is cleared to 0 is specified.

When TGRC or TGRD is designated for buffer operation, this setting is invalid and the register operates as a buffer register.

Table 16.13 TIORH (MTU0)

Bit 7	Bit 6	Bit 5	Bit 4		Description
IOB3	**IOB2**	**IOB1**	**IOB0**	**MTU0.TGRB Function**	**MTIOC0B Pin Function**
0	0	0	0	Output compare register	Output prohibited
0	0	0	1		Initial output is low. Low output at compare match.
0	0	1	0		Initial output is low. High output at compare match.
0	0	1	1		Initial output is low. Toggle output at compare match.
0	1	0	0		Output prohibited
0	1	0	1		Initial output is high. Low output at compare match.
0	1	1	0		Initial output is high. High output at compare match.
0	1	1	1		Initial output is high. Toggle output at compare match.
1	0	0	0	Input capture register	Input capture at rising edge.
1	0	0	1		Input capture at falling edge.
1	0	1	x		Input capture at both edges.
1	1	x	x		Capture input source is count clock in MTU1. Input capture at MTU1.TCNT up-count/down-count.

x: Don't care

Table 16.14 TIORL (MTU0)

Bit 7	Bit 6	Bit 5	Bit 4		Description
IOD3	IOD2	IOD1	IOD0	MTU0.TGRD Function	MTIOC0D Pin Function
0	0	0	0	Output compare register *1	Output prohibited
0	0	0	1		Initial output is low. Low output at compare match.
0	0	1	0		Initial output is low. High output at compare match.
0	0	1	1		Initial output is low. Toggle output at compare match.
0	1	0	0		Output prohibited
0	1	0	1		Initial output is high. Low output at compare match.
0	1	1	0		Initial output is high. High output at compare match.
0	1	1	1		Initial output is high. Toggle output at compare match.
1	0	0	0	Input capture register *1	Input capture at rising edge.
1	0	0	1		Input capture at falling edge.
1	0	1	x		Input capture at both edges.
1	1	x	x		Capture input source is count clock in MTU1. Input capture at MTU1.TCNT up-count/down-count.

x: Don't care

Note 1. When the MTU0.TMDR1.BFB is set to 1 and MTU0.TGRD is used as a buffer register, this setting is invalid and input capture/output compare is not generated.

Table 16.15 TIOR (MTU1)

Bit 7	Bit 6	Bit 5	Bit 4		Description
IOB3	**IOB2**	**IOB1**	**IOB0**	**MTU1.TGRB Function**	**MTIOC1B Pin Function**
0	0	0	0	Output compare register	Output prohibited
0	0	0	1		Initial output is low. Low output at compare match.
0	0	1	0		Initial output is low. High output at compare match.
0	0	1	1		Initial output is low. Toggle output at compare match.
0	1	0	0		Output prohibited
0	1	0	1		Initial output is high. Low output at compare match.
0	1	1	0		Initial output is high. High output at compare match.
0	1	1	1		Initial output is high. Toggle output at compare match.
1	0	0	0	Input capture register	Input capture at rising edge.
1	0	0	1		Input capture at falling edge.
1	0	1	x		Input capture at both edges.
1	1	x	x		Input capture at generation of MTU0.TGRC compare match/input capture.

x: Don't care

Table 16.16 TIOR (MTU2)

Bit 7	Bit 6	Bit 5	Bit 4		Description
IOB3	**IOB2**	**IOB1**	**IOB0**	**MTU2.TGRB Function**	**MTIOC2B Pin Function**
0	0	0	0	Output compare register	Output prohibited
0	0	0	1		Initial output is low. Low output at compare match.
0	0	1	0		Initial output is low. High output at compare match.
0	0	1	1		Initial output is low. Toggle output at compare match.
0	1	0	0		Output prohibited
0	1	0	1		Initial output is high. Low output at compare match.
0	1	1	0		Initial output is high. High output at compare match.
0	1	1	1		Initial output is high. Toggle output at compare match.
1	x	0	0	Input capture register	Input capture at rising edge.
1	x	0	1		Input capture at falling edge.
1	x	1	x		Input capture at both edges.

x: Don't care

Table 16.17 TIORH (MTU3)

Bit 7	Bit 6	Bit 5	Bit 4		Description
IOB3	IOB2	IOB1	IOB0	MTU3.TGRB Function	MTIOC3B Pin Function
0	0	0	0	Output compare register	Output prohibited
0	0	0	1		Initial output is low. Low output at compare match.
0	0	1	0		Initial output is low. High output at compare match.
0	0	1	1		Initial output is low. Toggle output at compare match.
0	1	0	0		Output prohibited
0	1	0	1		Initial output is high. Low output at compare match.
0	1	1	0		Initial output is high. High output at compare match.
0	1	1	1		Initial output is high. Toggle output at compare match.
1	x	0	0	Input capture register	Input capture at rising edge.
1	x	0	1		Input capture at falling edge.
1	x	1	x		Input capture at both edges.

x: Don't care

Table 16.18 TIORL (MTU3)

Bit 7	Bit 6	Bit 5	Bit 4		Description
IOD3	IOD2	IOD1	IOD0	MTU3.TGRD Function	MTIOC3D Pin Function
0	0	0	0	Output compare register *1	Output prohibited
0	0	0	1		Initial output is low. Low output at compare match.
0	0	1	0		Initial output is low. High output at compare match.
0	0	1	1		Initial output is low. Toggle output at compare match.
0	1	0	0		Output prohibited
0	1	0	1		Initial output is high. Low output at compare match.
0	1	1	0		Initial output is high. High output at compare match.
0	1	1	1		Initial output is high. Toggle output at compare match.
1	x	0	0	Input capture register *1	Input capture at rising edge.
1	x	0	1		Input capture at falling edge.
1	x	1	x		Input capture at both edges.

x: Don't care

Note 1. When the BFB bit in MTU3.TMDR1 is set to 1 and MTU3.TGRD is used as a buffer register, this setting is invalid and input capture/output compare is not generated.

Table 16.19 TIORH (MTU4)

Bit 7	Bit 6	Bit 5	Bit 4		Description
IOB3	IOB2	IOB1	IOB0	MTU4.TGRB Function	MTIOC4B Pin Function
0	0	0	0	Output compare register	Output prohibited
0	0	0	1		Initial output is low. Low output at compare match.
0	0	1	0		Initial output is low. High output at compare match.
0	0	1	1		Initial output is low. Toggle output at compare match.
0	1	0	0		Output prohibited
0	1	0	1		Initial output is high. Low output at compare match.
0	1	1	0		Initial output is high. High output at compare match.
0	1	1	1		Initial output is high. Toggle output at compare match.
1	x	0	0	Input capture register	Input capture at rising edge.
1	x	0	1		Input capture at falling edge.
1	x	1	x		Input capture at both edges.

x: Don't care

Table 16.20 TIORL (MTU4)

Bit 7	Bit 6	Bit 5	Bit 4		Description
IOD3	IOD2	IOD1	IOD0	MTU4.TGRD Function	MTIOC4D Pin Function
0	0	0	0	Output compare register*1	Output prohibited
0	0	0	1		Initial output is low. Low output at compare match.
0	0	1	0		Initial output is low. High output at compare match.
0	0	1	1		Initial output is low. Toggle output at compare match.
0	1	0	0		Output prohibited
0	1	0	1		Initial output is high. Low output at compare match.
0	1	1	0		Initial output is high. High output at compare match.
0	1	1	1		Initial output is high. Toggle output at compare match.
1	x	0	0	Input capture register *1	Input capture at rising edge.
1	x	0	1		Input capture at falling edge.
1	x	1	x		Input capture at both edges.

x: Don't care

Note 1. When the BFB bit in MTU4.TMDR1 is set to 1 and MTU4.TGRD is used as a buffer register, this setting is invalid and input capture/output compare is not generated.

Table 16.21 TIORH (MTU6)

Bit 7	Bit 6	Bit 5	Bit 4		Description
IOB3	IOB2	IOB1	IOB0	MTU6.TGRB Function	MTIOC6B Pin Function
0	0	0	0	Output compare register	Output prohibited
0	0	0	1		Initial output is low. Low output at compare match.
0	0	1	0		Initial output is low. High output at compare match.
0	0	1	1		Initial output is low. Toggle output at compare match.
0	1	0	0		Output prohibited
0	1	0	1		Initial output is high. Low output at compare match.
0	1	1	0		Initial output is high. High output at compare match.
0	1	1	1		Initial output is high. Toggle output at compare match.
1	x	0	0	Input capture register	Input capture at rising edge.
1	x	0	1		Input capture at falling edge.
1	x	1	x		Input capture at both edges.

x: Don't care

Table 16.22 TIORL (MTU6)

Bit 7	Bit 6	Bit 5	Bit 4		Description
IOD3	IOD2	IOD1	IOD0	MTU6.TGRD Function	MTIOC6D Pin Function
0	0	0	0	Output compare register *1	Output prohibited
0	0	0	1		Initial output is low. Low output at compare match.
0	0	1	0		Initial output is low. High output at compare match.
0	0	1	1		Initial output is low. Toggle output at compare match.
0	1	0	0		Output prohibited
0	1	0	1		Initial output is high. Low output at compare match.
0	1	1	0		Initial output is high. High output at compare match.
0	1	1	1		Initial output is high. Toggle output at compare match.
1	x	0	0	Input capture register *1	Input capture at rising edge.
1	x	0	1		Input capture at falling edge.
1	x	1	x		Input capture at both edges.

x: Don't care

Note 1. When the BFB bit in MTU6.TMDR1 is set to 1 and MTU6.TGRD is used as a buffer register, this setting is invalid and input capture/output compare is not generated.

Table 16.23 TIORH (MTU7)

Bit 7	Bit 6	Bit 5	Bit 4		Description
IOB3	IOB2	IOB1	IOB0	MTU7.TGRB Function	MTIOC7B Pin Function
0	0	0	0	Output compare register	Output prohibited
0	0	0	1		Initial output is low. Low output at compare match.
0	0	1	0		Initial output is low. High output at compare match.
0	0	1	1		Initial output is low. Toggle output at compare match.
0	1	0	0		Output prohibited
0	1	0	1		Initial output is high. Low output at compare match.
0	1	1	0		Initial output is high. High output at compare match.
0	1	1	1		Initial output is high. Toggle output at compare match.
1	x	0	0	Input capture register	Input capture at rising edge.
1	x	0	1		Input capture at falling edge.
1	x	1	x		Input capture at both edges.

x: Don't care

Table 16.24 TIORL (MTU7)

Bit 7	Bit 6	Bit 5	Bit 4		Description
IOD3	IOD2	IOD1	IOD0	MTU7.TGRD Function	MTIOC7D Pin Function
0	0	0	0	Output compare register *1	Output prohibited
0	0	0	1		Initial output is low. Low output at compare match.
0	0	1	0		Initial output is low. High output at compare match.
0	0	1	1		Initial output is low. Toggle output at compare match.
0	1	0	0		Output prohibited
0	1	0	1		Initial output is high. Low output at compare match.
0	1	1	0		Initial output is high. High output at compare match.
0	1	1	1		Initial output is high. Toggle output at compare match.
1	x	0	0	Input capture register*1	Input capture at rising edge.
1	x	0	1		Input capture at falling edge.
1	x	1	x		Input capture at both edges.

x: Don't care

Note 1. When the BFB bit in MTU7.TMDR1 is set to 1 and MTU7.TGRD is used as a buffer register, this setting is invalid and input capture/output compare is not generated.

Table 16.25 TIORH (MTU0)

Bit 3	Bit 2	Bit 1	Bit 0		Description
IOA3	IOA2	IOA1	IOA0	MTU0.TGRA Function	MTIOC0A Pin Function
0	0	0	0	Output compare register	Output prohibited
0	0	0	1		Initial output is low. Low output at compare match.
0	0	1	0		Initial output is low. High output at compare match.
0	0	1	1		Initial output is low. Toggle output at compare match.
0	1	0	0		Output prohibited
0	1	0	1		Initial output is high. Low output at compare match.
0	1	1	0		Initial output is high. High output at compare match.
0	1	1	1		Initial output is high. Toggle output at compare match.
1	0	0	0	Input capture register	Input capture at rising edge.
1	0	0	1		Input capture at falling edge.
1	0	1	x		Input capture at both edges.
1	1	x	x		Capture input source is count clock in MTU1 Input capture at generation of MTU1.TCNT up-count/ down-count

x: Don't care

Table 16.26 TIORL (MTU0)

Bit 3	Bit 2	Bit 1	Bit 0		Description
IOC3	IOC2	IOC1	IOC0	MTU0.TGRC Function	MTIOC0C Pin Function
0	0	0	0	Output compare register*1	Output prohibited
0	0	0	1		Initial output is low. Low output at compare match.
0	0	1	0		Initial output is low. High output at compare match.
0	0	1	1		Initial output is low. Toggle output at compare match.
0	1	0	0		Output prohibited
0	1	0	1		Initial output is high. Low output at compare match.
0	1	1	0		Initial output is high. High output at compare match.
0	1	1	1		Initial output is high. Toggle output at compare match.
1	0	0	0	Input capture register*1	Input capture at rising edge.
1	0	0	1		Input capture at falling edge.
1	0	1	x		Input capture at both edges.
1	1	x	x		Capture input source is count clock in MTU1 Input capture at generation of MTU1.TCNT up-count/down-count

x: Don't care

Note 1. When the BFA bit in MTU0.TMDR1 is set to 1 and MTU0.TGRC is used as a buffer register, this setting is invalid and input capture/output compare is not generated.

Table 16.27 TIOR (MTU1)

Bit 3	Bit 2	Bit 1	Bit 0		Description
IOA3	IOA2	IOA1	IOA0	MTU1.TGRA Function	MTIOC1A Pin Function
0	0	0	0	Output compare register	Output prohibited
0	0	0	1		Initial output is low. Low output at compare match.
0	0	1	0		Initial output is low. High output at compare match.
0	0	1	1		Initial output is low. Toggle output at compare match.
0	1	0	0		Output prohibited
0	1	0	1		Initial output is high. Low output at compare match.
0	1	1	0		Initial output is high. High output at compare match.
0	1	1	1		Initial output is high. Toggle output at compare match.
1	0	0	0	Input capture register	Input capture at rising edge.
1	0	0	1		Input capture at falling edge.
1	0	1	x		Input capture at both edges.
1	1	x	x		Input capture at generation of MTU0.TGRA compare match/input capture.

x: Don't care

Table 16.28 TIOR (MTU2)

Bit 3	Bit 2	Bit 1	Bit 0		Description
IOA3	IOA2	IOA1	IOA0	MTU2.TGRA Function	MTIOC2A Pin Function
0	0	0	0	Output compare register	Output prohibited
0	0	0	1		Initial output is low. Low output at compare match.
0	0	1	0		Initial output is low. High output at compare match.
0	0	1	1		Initial output is low. Toggle output at compare match.
0	1	0	0		Output prohibited
0	1	0	1		Initial output is high. Low output at compare match.
0	1	1	0		Initial output is high. High output at compare match.
0	1	1	1		Initial output is high. Toggle output at compare match.
1	x	0	0	Input capture register	Input capture at rising edge.
1	x	0	1		Input capture at falling edge.
1	x	1	x		Input capture at both edges.

x: Don't care

Table 16.29 TIORH (MTU3)

Bit 3	Bit 2	Bit 1	Bit 0		Description
IOA3	IOA2	IOA1	IOA0	MTU3.TGRA Function	MTIOC3A Pin Function
0	0	0	0	Output compare register	Output prohibited
0	0	0	1		Initial output is low. Low output at compare match.
0	0	1	0		Initial output is low. High output at compare match.
0	0	1	1		Initial output is low. Toggle output at compare match.
0	1	0	0		Output prohibited
0	1	0	1		Initial output is high. Low output at compare match.
0	1	1	0		Initial output is high. High output at compare match.
0	1	1	1		Initial output is high. Toggle output at compare match.
1	x	0	0	Input capture register	Input capture at rising edge.
1	x	0	1		Input capture at falling edge.
1	x	1	x		Input capture at both edges.

x: Don't care

Table 16.30 TIORL (MTU3)

Bit 3	Bit 2	Bit 1	Bit 0		Description
IOC3	IOC2	IOC1	IOC0	MTU3.TGRC Function	MTIOC3C Pin Function
0	0	0	0	Output compare register *1	Output prohibited
0	0	0	1		Initial output is low. Low output at compare match.
0	0	1	0		Initial output is low. High output at compare match.
0	0	1	1		Initial output is low. Toggle output at compare match.
0	1	0	0		Output prohibited
0	1	0	1		Initial output is high. Low output at compare match.
0	1	1	0		Initial output is high. High output at compare match.
0	1	1	1		Initial output is high. Toggle output at compare match.
1	x	0	0	Input capture register *1	Input capture at rising edge.
1	x	0	1		Input capture at falling edge.
1	x	1	x		Input capture at both edges.

x: Don't care

Note 1. When the BFA bit in MTU3.TMDR1 is set to 1 and MTU3.TGRC is used as a buffer register, this setting is invalid and input capture/output compare is not generated.

Table 16.31 TIORH (MTU4)

Bit 3	Bit 2	Bit 1	Bit 0		Description
IOA3	IOA2	IOA1	IOA0	MTU4.TGRA Function	MTIOC4A Pin Function
0	0	0	0	Output compare register	Output prohibited
0	0	0	1		Initial output is low. Low output at compare match.
0	0	1	0		Initial output is low. High output at compare match.
0	0	1	1		Initial output is low. Toggle output at compare match.
0	1	0	0		Output prohibited
0	1	0	1		Initial output is high. Low output at compare match.
0	1	1	0		Initial output is high. High output at compare match.
0	1	1	1		Initial output is high. Toggle output at compare match.
1	x	0	0	Input capture register	Input capture at rising edge.
1	x	0	1		Input capture at falling edge.
1	x	1	x		Input capture at both edges.

x: Don't care

Table 16.32 TIORL (MTU4)

Bit 3	Bit 2	Bit 1	Bit 0		Description
IOC3	IOC2	IOC1	IOC0	MTU4.TGRC Function	MTIOC4C Pin Function
0	0	0	0	Output compare register *1	Output prohibited
0	0	0	1		Initial output is low. Low output at compare match.
0	0	1	0		Initial output is low. High output at compare match.
0	0	1	1		Initial output is low. Toggle output at compare match.
0	1	0	0		Output prohibited
0	1	0	1		Initial output is high. Low output at compare match.
0	1	1	0		Initial output is high. High output at compare match.
0	1	1	1		Initial output is high. Toggle output at compare match.
1	x	0	0	Input capture register *1	Input capture at rising edge.
1	x	0	1		Input capture at falling edge.
1	x	1	x		Input capture at both edges.

x: Don't care

Note 1. When the BFA bit in MTU4.TMDR1 is set to 1 and MTU4.TGRC is used as a buffer register, this setting is invalid and input capture/output compare is not generated.

Table 16.33 TIORH (MTU6)

Bit 3	Bit 2	Bit 1	Bit 0		Description
IOA3	IOA2	IOA1	IOA0	MTU6.TGRA Function	MTIOC6A Pin Function
0	0	0	0	Output compare register	Output prohibited
0	0	0	1		Initial output is low. Low output at compare match.
0	0	1	0		Initial output is low. High output at compare match.
0	0	1	1		Initial output is low. Toggle output at compare match.
0	1	0	0		Output prohibited
0	1	0	1		Initial output is high. Low output at compare match.
0	1	1	0		Initial output is high. High output at compare match.
0	1	1	1		Initial output is high. Toggle output at compare match.
1	x	0	0	Input capture register	Input capture at rising edge.
1	x	0	1		Input capture at falling edge.
1	x	1	x		Input capture at both edges.

x: Don't care

Table 16.34 TIORL (MTU6)

Bit 3	Bit 2	Bit 1	Bit 0	MTU6.TGRC Function	Description
IOC3	IOC2	IOC1	IOC0		MTIOC6C Pin Function
0	0	0	0	Output compare register *1	Output prohibited
0	0	0	1		Initial output is low. Low output at compare match.
0	0	1	0		Initial output is low. High output at compare match.
0	0	1	1		Initial output is low. Toggle output at compare match.
0	1	0	0		Output prohibited
0	1	0	1		Initial output is high. Low output at compare match.
0	1	1	0		Initial output is high. High output at compare match.
0	1	1	1		Initial output is high. Toggle output at compare match.
1	x	0	0	Input capture register *1	Input capture at rising edge.
1	x	0	1		Input capture at falling edge.
1	x	1	x		Input capture at both edges.

x: Don't care

Note 1. When the BFA bit in MTU6.TMDR1 is set to 1 and MTU6.TGRC is used as a buffer register, this setting is invalid and input capture/output compare is not generated.

Table 16.35 TIORH (MTU7)

Bit 3	Bit 2	Bit 1	Bit 0		Description
IOA3	IOA2	IOA1	IOA0	MTU7.TGRA Function	MTIOC7A Pin Function
0	0	0	0	Output compare register	Output prohibited
0	0	0	1		Initial output is low. Low output at compare match.
0	0	1	0		Initial output is low. High output at compare match.
0	0	1	1		Initial output is low. Toggle output at compare match.
0	1	0	0		Output prohibited
0	1	0	1		Initial output is high. Low output at compare match.
0	1	1	0		Initial output is high. High output at compare match.
0	1	1	1		Initial output is high. Toggle output at compare match.
1	x	0	0	Input capture register	Input capture at rising edge.
1	x	0	1		Input capture at falling edge.
1	x	1	x		Input capture at both edges.

x: Don't care

Table 16.36 TIORL (MTU7)

Bit 3	Bit 2	Bit 1	Bit 0	MTU7.TGRC Function	Description
IOC3	IOC2	IOC1	IOC0		MTIOC7C Pin Function
0	0	0	0	Output compare register *1	Output prohibited
0	0	0	1		Initial output is low. Low output at compare match.
0	0	1	0		Initial output is low. High output at compare match.
0	0	1	1		Initial output is low. Toggle output at compare match.
0	1	0	0		Output prohibited
0	1	0	1		Initial output is high. Low output at compare match.
0	1	1	0		Initial output is high. High output at compare match.
0	1	1	1		Initial output is high. Toggle output at compare match.
1	x	0	0	Input capture register *1	Input capture at rising edge.
1	x	0	1		Input capture at falling edge.
1	x	1	x		Input capture at both edges.

x: Don't care

Note 1. When the BFA bit in MTU7.TMDR1 is set to 1 and MTU7.TGRC is used as a buffer register, this setting is invalid and input capture/output compare is not generated.

Table 16.37 TIORU, TIORV, and TIORW (MTU5)

Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	MTU5.TGRU, MTU5.TGRV, MTU5.TGRW Function	Description
IOC4	IOC3	IOC2	IOC1	IOC0		MTIC5U, MTIC5V, MTIC5W Pin Function
0	0	0	0	0	Compare match register	Compare match
0	0	0	0	1		Setting prohibited
0	0	0	1	x		Setting prohibited
0	0	1	x	x		Setting prohibited
0	1	x	x	x		Setting prohibited
1	0	0	0	0	Input capture register	Setting prohibited
1	0	0	0	1		Input capture at rising edge.
1	0	0	1	0		Input capture at falling edge.
1	0	0	1	1		Input capture at both edges.
1	0	1	x	x		Setting prohibited
1	1	0	0	0		Setting prohibited
1	1	0	0	1		Measurement of low pulse width of external input signal. Capture at trough in complementary PWM mode.
1	1	0	1	0		Measurement of low pulse width of external input signal. Capture at crest of complementary PWM mode.
1	1	0	1	1		Measurement of low pulse width of external input signal. Capture at crest and trough of complementary PWM mode.
1	1	1	0	0		Setting prohibited
1	1	1	0	1		Measurement of high pulse width of external input signal. Capture at trough in complementary PWM mode.
1	1	1	1	0		Measurement of high pulse width of external input signal. Capture at crest of complementary PWM mode.
1	1	1	1	1		Measurement of high pulse width of external input signal. Capture at crest and trough of complementary PWM mode.

x: Don't care

16.2.5 Timer Compare Match Clear Register (TCNTCMPCLR)

Address: 000C 1CB6h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	CMPCLR5U	CMPCLR5V	CMPCLR5W
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	CMPCLR5W	TCNT Compare Clear 5W	0: Disables MTU5.TCNTW to be cleared to 0000h at MTU5.TCNTW and MTU5.TGRW compare match or input capture 1: Enables MTU5.TCNTW to be cleared to 0000h at MTU5.TCNTW and MTU5.TGRW compare match or input capture	R/W
b1	CMPCLR5V	TCNT Compare Clear 5V	0: Disables MTU5.TCNTV to be cleared to 0000h at MTU5.TCNTV and MTU5.TGRV compare match or input capture 1: Enables MTU5.TCNTV to be cleared to 0000h at MTU5.TCNTV and MTU5.TGRV compare match or input capture	R/W
b2	CMPCLR5U	TCNT Compare Clear 5U	0: Disables MTU5.TCNTU to be cleared to 0000h at MTU5.TCNTU and MTU5.TGRU compare match or input capture 1: Enables MTU5.TCNTU to be cleared to 0000h at MTU5.TCNTU and MTU5.TGRU compare match or input capture	R/W
b7 to b3	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W

TCNTCMPCLR specifies requests to clear MTU5.TCNTU, MTU5.TCNTV, and MTU5.TCNTW. The MTU has one TCNTCMPCLR (on MTU5).

CMPCLR5n Bits (TCNT Compare Clear 5n; n = U, V, W)

These bits are used to enable or disable requests to clear MTU5.TCNTn on compare match or input capture for MTU5.TCNTn and MTU5.TGRn.

16.2.6 Timer Interrupt Enable Register (TIER)

- TIER (MTU1, MTU2)

Address: MTU1.TIER 000C 1384h, MTU2.TIER 000C 1404h

	b7	b6	b5	b4	b3	b2	b1	b0
	TTGE	—	TCIEU	TCIEV	—	—	TGIEB	TGIEA
Value after reset:	0	0	0	0	0	0	0	0

- TIER (MTU0, MTU3, MTU6)

Address: MTU0.TIER 000C 1304h, MTU3.TIER 000C 1208h, MTU6.TIER 000C 1A08h

	b7	b6	b5	b4	b3	b2	b1	b0
	TTGE	—	—	TCIEV	TGIED	TGIEC	TGIEB	TGIEA
Value after reset:	0	0	0	0	0	0	0	0

- TIER (MTU4, MTU7)

Address: MTU4.TIER 000C 1209h, MTU7.TIER 000C 1A09h

	b7	b6	b5	b4	b3	b2	b1	b0
	TTGE	TTGE2	—	TCIEV	TGIED	TGIEC	TGIEB	TGIEA
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	TGIEA	TGR Interrupt Enable A	0: Interrupt requests (TGIA) disabled 1: Interrupt requests (TGIA) enabled	R/W
b1	TGIEB	TGR Interrupt Enable B	0: Interrupt requests (TGIB) disabled 1: Interrupt requests (TGIB) enabled	R/W
b2	TGIEC	TGR Interrupt Enable C	0: Interrupt requests (TGIC) disabled 1: Interrupt requests (TGIC) enabled	R/W
b3	TGIED	TGR Interrupt Enable D	0: Interrupt requests (TGID) disabled 1: Interrupt requests (TGID) enabled	R/W
b4	TCIEV	Overflow Interrupt Enable	0: Interrupt requests (TCIV) disabled 1: Interrupt requests (TCIV) enabled	R/W
b5	TCIEU	Underflow Interrupt Enable	0: Interrupt requests (TCIU) disabled 1: Interrupt requests (TCIU) enabled	R/W
b6	TTGE2	A/D Converter Start Request Enable 2	0: A/D converter start request generation by MTUn.TCNT underflow (trough) disabled 1: A/D converter start request generation by MTUn.TCNT underflow (trough) enabled	R/W
b7	TTGE	A/D Converter Start Request Enable	0: A/D converter start request generation disabled 1: A/D converter start request generation enabled	R/W

n = 4 or 7

TIER enables or disables interrupt requests in each channel. The MTU3 has a total of nine TIER registers, two for MTU0 and one each for MTU1 to MTU7.

TGIEA and TGIEB Bits (TGR Interrupt Enable A and B)

Each bit enables or disables interrupt requests (TGIn) by the TSR.TGFn flag when the TSR.TGFn flag is set to 1 (n = A or B).

TGIEC and TGIED Bits (TGR Interrupt Enable C and D)

Each bit enables or disables interrupt requests (TGIn) in MTU0, MTU3, MTU4, MTU6, and MTU7 by the TSR.TGFn flag when the TSR.TGFn flag is set to 1 (n = C or D).
In MTU1 and MTU2, these bits are reserved. They are always read as 0. The write value should be 0.

TCIEV Bit (Overflow Interrupt Enable)

This bit enables or disables interrupt requests (TCIV) by the TSR.TCFV flag when the TSR.TCFV flag is set to 1.

TCIEU Bit (Underflow Interrupt Enable)

This bit enables or disables interrupt requests (TCIU) in MTU1 and MTU2 by the TSR.TCFU flag when the TSR.TCFU flag is set to 1.
In MTU0, MTU3, MTU4, MTU6, and MTU7, this bit is reserved. It is always read as 0. The write value should be 0.

TTGE2 Bit (A/D Converter Start Request Enable 2)

This bit enables or disables generation of A/D converter start requests by MTUn.TCNT underflow (trough) in complementary PWM mode (n = 4 or 7).
In MTU0 to MTU3, and MTU6, this bit is reserved. It is always read as 0. The write value should be 0.

TTGE Bit (A/D Converter Start Request Enable)

This bit enables or disables generation of A/D converter start requests by TGRA input capture/compare match.

- TIER2 (MTU0)

Address: 000C 1324h

	b7	b6	b5	b4	b3	b2	b1	b0
	TTGE2	—	—	—	—	—C	TGIEF	TGIEE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	TGIEE	TGR Interrupt Enable E	0: Interrupt requests (TGIE) disabled 1: Interrupt requests (TGIE) enabled	R/W
b1	TGIEF	TGR Interrupt Enable F	0: Interrupt requests (TGIF) disabled 1: Interrupt requests (TGIF) enabled	R/W
b6 to b2	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W
b7	TTGE2	A/D Converter Start Request Enable 2	0: A/D converter start request generation by compare match between MTU0.TCNT and MTU0.TGRE disabled 1: A/D converter start request generation by compare match between MTU0.TCNT and MTU0.TGRE enabled	R/W

TGIEE and TGIEF Bits (TGR Interrupt Enable E and F)

Each bit enables or disables interrupt requests by compare match between MTU0.TCNT and MTU0.TGRn (n = E or F).

TTGE2 Bit (A/D Converter Start Request Enable 2)

Each bit enables or disables interrupt requests by compare match between MTU0.TCNT and MTU0.TGRE.

- TIER (MTU5)

Address: MTU5.TIER 000C 1CB2h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	TGIE5U	TGIE5V	TGIE5W
Value after reset:	0	0	0	0	0	0	0	1

Bit	Symbol	Bit Name	Description	R/W
b0	TGIE5W	TGR Interrupt Enable 5W	0: Interrupt requests TGIW5 disabled 1: Interrupt requests TGIW5 enabled	R/W
b1	TGIE5V	TGR Interrupt Enable 5V	0: Interrupt requests TGIV5 disabled 1: Interrupt requests TGIV5 enabled	R/W
b2	TGIE5U	TGR Interrupt Enable 5U	0: Interrupt requests TGIU5 disabled 1: Interrupt requests TGIU5 enabled	R/W
b7 to b3	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W

TGIE5n Bits (TGR Interrupt Enable 5n)

Each bit enables or disables interrupt requests (TGIn5) by the MTU5.TSR.CMFn5 flag when the MTU5.TSR.CMFn5 flag is set to 1 (n = U, V, or W).

16.2.7 Timer Status Register (TSR)

- TSR (MTU0)

Address: 000C 1305h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	TCFV	TGFD	TGFC	TGFB	TGFA
Value after reset:	1	1	0	0	0	0	0	0

TSR (MTU1, MTU2)

Address: MTU1.TSR 000C 1385h, MTU2.TSR 000C 1405h

	b7	b6	b5	b4	b3	b2	b1	b0
	TCFD	—	TCFU	TCFV	—	—	TGFB	TGFA
Value after reset:	1	1	0	0	0	0	0	0

- TSR (MTU3, MTU4, MTU6, MTU7)

Address: MTU3.TSR 000C 122Ch, MTU4.TSR 000C 122Dh, MTU6.TSR 000C 1A2Ch, MTU7.TSR 000C 1A2Dh

	b7	b6	b5	b4	b3	b2	b1	b0
	TCFD	—	—	TCFV	TGFD	TGFC	TGFB	TGFA
Value after reset:	1	1	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	TGFA	Input Capture/Output Compare Flag A	0: Neither TGRA input capture nor compare match generated 1: TGRA input capture or compare match generated	R/(W)*1
b1	TGFB	Input Capture/Output Compare Flag B	0: Neither TGRB input capture nor compare match generated 1: TGRB input capture or compare match generated	R/(W)*1
b2	TGFC	Input Capture/Output Compare Flag C	0: Neither TGRC input capture nor compare match generated 1: TGRC input capture or compare match generated	R/(W)*1
b3	TGFD	Input Capture/Output Compare Flag D	0: Neither TGRD input capture nor compare match generated 1: TGRD input capture or compare match generated	R/(W)*1
b4	TCFV	Overflow Flag	0: No TCNT overflow generated 1: TCNT overflow generated	R/(W)*1
b5	TCFU	Underflow flag	0: No TCNT underflow generated when MTU1 or MTU2 is in phase counting mode 1: TCNT underflow generated when MTU1 or MTU2is in phase counting mode	R/(W)*1
b6	—	Reserved	This bit is always read as 1. The write value should be 1.	R/W
b7	TCFD	Count Direction Flag	0: TCNT counts down 1: TCNT counts up	R

Note 1. Writing 0 to this bit after reading it as 1 clears the flag and is the only allowed way.

TSR indicates the status of each channel. The MTU3 has a total of nine TSR registers, two for MTU0 and one each for MTU1 to MTU7.

TGFA Flag (Input Capture/Output Compare Flag A)

Status flag that indicates the occurrence of TGRA input capture or compare match. Only 0 can be written to clear the flag.

[Setting conditions]

- When TCNT = TGRA while TGRA is functioning as output compare register
- When TCNT value is transferred to TGRA by input capture signal while TGRA is functioning as input capture register

[Clearing conditions]

- When 0 is written to TGFA after reading TGFA = 1

TGFB Flag (Input Capture/Output Compare Flag B)

Status flag that indicates the occurrence of TGRB input capture or compare match. Only 0 can be written to clear the flag.

[Setting conditions]

- When TCNT = TGRB while TGRB is functioning as output compare register
- When TCNT value is transferred to TGRB by input capture signal while TGRB is functioning as input capture register

[Clearing conditions]

- When 0 is written to TGFB after reading TGFB = 1

TGFC Flag (Input Capture/Output Compare Flag C)

Status flag that indicates the occurrence of TGRC input capture or compare match. Only 0 can be written to clear the flag.

[Setting conditions]

- When TCNT = TGRC while TGRC is functioning as output compare register
- When TCNT value is transferred to TGRC by input capture signal while TGRC is functioning as input capture register

[Clearing conditions]

- When 0 is written to TGFC after reading TGFC = 1

In MTU1 and MTU2, this bit is reserved. It is always read as 0. The write value should be 0.

TGFD Flag (Input Capture/Output Compare Flag D)

Status flag that indicates the occurrence of TGRD input capture or compare match. Only 0 can be written to clear the flag.

[Setting conditions]

- When TCNT = TGRD while TGRD is functioning as output compare register
- When TCNT value is transferred to TGRD by input capture signal while TGRD is functioning as input capture register

[Clearing conditions]

- When 0 is written to TGFD after reading TGFD = 1

In MTU1 and MTU2, this bit is reserved. It is always read as 0. The write value should be 0.

TCFV Flag (Overflow Flag)

Status flag that indicates that TCNT overflow has occurred. Only 0 can be written to clear the flag.
[Setting conditions]

- When the TCNT value overflows (changes from FFFFh to 0000h)
- In MTU4 to MTU7, when the MTU4.TCNT or MTU7.TCNT value underflows (changes from 0001h to 0000h) in complementary PWM mode, this flag is also set.

[Clearing conditions]

- When 0 is written to TCFV after reading TCFV = 1

TCFU Flag (Underflow Flag)

Status flag that indicates that TCNT underflow has occurred when MTU1 or MTU2 is set to phase counting mode. Only 0 can be written to clear the flag.
[Setting conditions]

- When the TCNT value underflows (changes from 0000h to FFFFh)

[Clearing condition]

- When 0 is written to TCFU after reading TCFU = 1
- In MTU0, MTU3, MTU4, MTU6, and MTU7, this bit is reserved. It is always read as 0. The write value should be 0.

TCFD Flag (Count Direction Flag)

Status flag that shows the direction in which TCNT counts in MTU1 to MTU4, MTU6, and MTU7.
In MTU0, this bit is reserved. It is always read as 1. The write value should be 1.

- TSR2 (MTU0)

Address: 000C 1325h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	TGFF	TGFE
Value after reset:	1	1	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	TGFE	Compare Match Flag E	0: No compare match between the MTU0.TCNT and MTU0.TGRE generated 1: Compare match between the MTU0.TCNT and MTU0.TGRE generated	R/(W)*1
b1	TGFF	Compare Match Flag F	0: No compare match between the MTU0.TCNT and MTU0.TGRF generated 1: Compare match between the MTU0.TCNT and MTU0.TGRF generated	R/(W)*1
b5 to b2	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W
b7, b6	—	Reserved	These bits are always read as 1. The write value should be 1.	R/W

Note 1. Writing 0 to this bit after reading it as 1 clears the flag and is the only allowed way.

TGFE Flag (Compare Match Flag E)

Status flag that indicates the occurrence of compare match between the MTU0.TCNT and MTU0.TGRE. Only 0 can be written to clear the flag.

[Setting condition]

- When MTU0.TCNT = MTU0.TGRE while TGRE is functioning as a compare register

[Clearing condition]

- When 0 is written to TGFE after reading TGFE = 1

TGFF Flag (Compare Match Flag F)

Status flag that indicates the occurrence of compare match between the MTU0.TCNT and MTU0.TGRF. Only 0 can be written to clear the flag.

[Setting condition]

- When MTU0.TCNT = MTU0.TGRF while TGRF is functioning as a compare register

[Clearing condition]

- When 0 is written to TGFF after reading TGFF = 1

- TSR (MTU5)

Address: 000C 1CB0h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	CMFU5	CMFV5	CMFW5
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbo	Bit Name	Description	R/W
b0	CMFW5	Compare Match/Input Capture Flag W5	0: Neither MTU5.TGRW input capture nor compare match generated 1: MTU5.TGRW input capture or compare match generated	R/(W)*1
b1	CMFV5	Compare Match/Input Capture Flag V5	0: Neither MTU5.TGRV input capture nor compare match generated 1: MTU5.TGRV input capture or compare match generated	R/(W)*1
b2	CMFU5	Compare Match/Input Capture Flag U5	0: Neither MTU5.TGRU input capture nor compare match generated 1: MTU5.TGRU input capture or compare match generated	R/(W)*1
b7 to b3	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W

Note 1. Writing 0 to this bit after reading it as 1 clears the flag and is the only allowed way.

CMFn5 Flag (Compare Match/Input Capture Flag n5) (n = U, V, W)

Status flags that indicate the occurrence of MTU5.TGRn input capture or compare match. Only 0 can be written to clear the flag.

[Setting conditions]

- When MTU5.TCNTn = MTU5.TGRn while MTU5.TGRn is functioning as a compare match register
- When MTU5.TCNTn value is transferred to MTU5.TGRn by input capture signal while MTU5.TGRn is functioning as an input capture register
- When MTU5.TCNTn value is transferred to MTU5.TGRn while MTU5.TGRn is functioning as a register for measuring the pulse width of the external input signal.*1

[Clearing conditions]

- When 0 is written to CMFn5 after reading CMFn5 = 1

Note 1. The transfer timing is specified by the IOC[4:0] bits in MTU5.TIORU, MTU5.TIORV, and MTU5.TIORW.

16.2.8 Timer Buffer Operation Transfer Mode Register (TBTM)

- MTU0.TBTM

Address: 000C 1326h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	TTSE	TTSB	TTSA
Value after reset:	0	0	0	0	0	0	0	0

- MTU3.TBTM, MTU4.TBTM, MTU6.TBTM, MTU7.TBTM

Address: MTU3.TBTM 000C 1238h, MTU4.TBTM 000C 1239h
MTU6.TBTM 000C 1A38h, MTU7.TBTM 000C 1A39h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	TTSB	TTSA
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	TTSA	Timing Select A	0: When compare match A occurs in each channel, data is transferred from TGRC to TGRA 1: When TCNT is cleared in each channel, data is transferred from TGRC to TGRA	R/W
b1	TTSB	Timing Select B	0: When compare match B occurs in each channel, data is transferred from TGRD to TGRB 1: When TCNT is cleared in each channel, data is transferred from TGRD to TGRB	R/W
b2	TTSE	Timing Select E	0: When compare match E occurs in MTU0, data is transferred from MTU0.TGRF to MTU0.TGRE 1: When MTU0.TCNT is cleared in MTU0, data is transferred from MTU0.TGRF to MTU0.TGRE	R/W
b7 to b3	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W

TBTM specifies the timing for transferring data from the buffer register to the timer general register in PWM mode. The MTU3 has a total of five TBTM registers, one each for MTU0, MTU3, MTU4, MTU6, and MTU7.

TTSA Bit (Timing Select A)

This bit specifies the timing for transferring data from TGRC to TGRA in each channel when they are used together for buffer operation. When a channel is not set to PWM mode, do not set the TTSA bit in the channel to 1.

TTSB Bit (Timing Select B)

This bit specifies the timing for transferring data from TGRD to TGRB in each channel when they are used together for buffer operation. When a channel is not set to PWM mode, do not set the TTSB bit in the channel to 1.

TTSE Bit (Timing Select E)

This bit specifies the timing for transferring data from MTU0.TGRF to MTU0.TGRE when they are used together for buffer operation.
In MTU3, MTU4, MTU6 and MTU7, this bit is reserved. It is always read as 0 and the write value should be 0. When a channel is not set to PWM mode, do not set the TTSE bit in the channel to 1.

16.2.9 Timer Input Capture Control Register (TICCR)

Address: 000C 1390h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	I2BE	I2AE	I1BE	I1AE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	I1AE	Input Capture Enable	0: Does not include the MTIOC1A pin in the MTU2.TGRA input capture conditions 1: Includes the MTIOC1A pin in the MTU2.TGRA input capture conditions	R/W
b1	I1BE	Input Capture Enable	0: Does not include the TMTIOC1B pin in the MTU2.TGRB input capture conditions 1: Includes the MTIOC1B pin in the MTU2.TGRB input capture conditions	R/W
b2	I2AE	Input Capture Enable	0: Does not include the MTIOC2A pin in the MTU1.TGRA input capture conditions 1: Includes the MTIOC2A pin in the MTU1.TGRA input capture conditions	R/W
b3	I2BE	Input Capture Enable	0: Does not include the MTIOC2B pin in the MTU1.TGRB input capture conditions 1: Includes the MTIOC2B pin in the MTU1.TGRB input capture conditions	R/W
b7 to b4	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W

TICCR specifies input capture conditions when MTU1.TCNT and MTU2.TCNT are cascaded. The MTU3 has one TICCR for MTU1.

I1AE Bit (Input Capture Enable)

This bit selects or deselects the signal on the MTIOC1A pin as a condition for input capture to MTU2.TGRA.

I1BE Bit (Input Capture Enable)

This bit selects or deselects the signal on the MTIOC1B pin as a condition for input capture to MTU2.TGRB.

I2AE Bit (Input Capture Enable)

This bit selects or deselects the signal on the MTIOC2A pin as a condition for input capture to MTU1.TGRA.

I2BE Bit (Input Capture Enable)

This bit selects or deselects the signal on the MTIOC2B pin as a condition for input capture to MTU1.TGRB.

16.2.10 Timer Synchronous Clear Register (TSYCR)

Address: 000C 1A50h

	b7	b6	b5	b4	b3	b2	b1	b0
	CE0A	CE0B	CE0C	CE0D	CE1A	CE1B	CE2A	CE2B
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	CE2B	Clear Enable 2B	0: Disables counter clearing by the TGFB flag setting in MTU2.TSR 1: Enables counter clearing by the TGFB flag setting in MTU2.TSR	R/W
b1	CE2A	Clear Enable 2A	0: Disables counter clearing by the TGFA flag setting in MTU2.TSR 1: Enables counter clearing by the TGFA flag setting in MTU2.TSR	R/W
b2	CE1B	Clear Enable 1B	0: Disables counter clearing by the TGFB flag setting in MTU1.TSR 1: Enables counter clearing by the TGFB flag setting in MTU1.TSR	R/W
b3	CE1A	Clear Enable 1A	0: Disables counter clearing by the TGFA flag setting in MTU1.TSR 1: Enables counter clearing by the TGFA flag setting in MTU1.TSR	R/W
b4	CE0D	Clear Enable 0D	0: Disables counter clearing by the TGFD flag setting in MTU0.TSR 1: Enables counter clearing by the TGFD flag setting in MTU0.TSR	R/W
b5	CE0C	Clear Enable 0C	0: Disables counter clearing by the TGFC flag setting in MTU0.TSR 1: Enables counter clearing by the TGFC flag setting in MTU0.TSR	R/W
b6	CE0B	Clear Enable 0B	0: Disables counter clearing by the TGFB flag setting in MTU0.TSR 1: Enables counter clearing by the TGFB flag setting in MTU0.TSR	R/W
b7	CE0A	Clear Enable 0A	0: Disables counter clearing by the TGFA flag setting in MTU0.TSR 1: Enables counter clearing by the TGFA flag setting in MTU0.TSR	R/W

TSYCR specifies synchronous clear conditions for MTU6.TCNT and MTU7.TCNT. The MTU3 has one TSYCR for MTU1.

CEnm Bits (Clear Enable nm; n = 0, 1, 2; m = A, B, C, D)

These bits enable or disable clearing in response to setting of the TGFm flag in MTUn.TSR.

16.2.11 Timer Counter (TCNT)

Address: MTU0.TCNT 000C 1306h, MTU1.TCNT 000C 1386h, MTU2.TCNT 000C 1406h, MTU3.TCNT 000C 10h,
MTU4.TCNT 000C 1212h, MTU5.TCNTU 000C 1C80h, MTU5.TCNTV 000C 1C90h, MTU5.TCNTW 000C 1CA0h,
MTU6.TCNT 000C 1A10h, MTU7.TCNT 000C 1A12h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Note 1. TCNT must not be accessed in eight bits; it should always be accessed in 16 bits.

TCNT is a 16-bit readable/writable counter. The MTU3 has a total of ten TCNT counters, one each for MTU0 to MTU4, MTU6, and MTU7 and three (MTU5.TCNTU, TCNTUV, and TCNTUW) for MTU5.

TCNT is initialized to 0000h by a reset.

TCNT must not be accessed in eight bits; it should always be accessed in 16 bits.

16.2.12 Timer General Register (TGR)

Address: MTU0.TGRA 000C 1308h, MTU0.TGRB 000C 130Ah, MTU0.TGRC 000C 130Ch, MTU0.TGRD 000C 130Eh, MTU0.TGRE 000C 1320h, MTU0.TGRF 000C 1322h, MTU1.TGRA 000C 1388h, MTU1.TGRB 000C 138Ah, MTU2.TGRA 000C 1408h, MTU2.TGRB 000C 140Ah, MTU3.TGRA 000C 1218h, MTU3.TGRB 000C 121Ah, MTU3.TGRC 000C 1224h, MTU3.TGRD 000C 1226h, MTU3.TGRE 000C 1272h MTU4.TGRA 000C 121Ch, MTU4.TGRB 000C 121Eh, MTU4.TGRC 000C 1228h, MTU4.TGRD 000C 122Ah, MTU4.TGRE 000C 1274h, MTU4.TGRF 000C 1276h, MTU5.TGRU 000C 1C82h, MTU5.TGRV 000C 1C92h, MTU5.TGRW 000C 1CA2h, MTU6.TGRA 000C 1A18h, MTU6.TGRB 000C 1A1Ah, MTU6.TGRC 000C 1A24h, MTU6.TGRD 000C 1A26h, MTU6.TGRE 000C 1A72h, MTU7.TGRA 000C 1A1Ch, MTU7.TGRB 000C 1A1Eh, MTU7.TGRC 000C 1A28h, MTU7.TGRD 000C 1A2Ah, MTU7.TGRE 000C 1A74h, MTU7.TGRF 000C 1A76h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Note 1. TGR must not be accessed in eight bits; it should always be accessed in 16 bits. TGR is initialized to FFFFh.

TGR is a 16-bit readable/writable register. The MTU3 has a total of 35 TGR registers, six each for MTU0, two each for MTU1 and MTU2, five each for MTU3 and MTU6, six each for MTU4 and MTU7, and three for MTU5.

TGRA, TGRB, TGRC, and TGRD function as either output compare or input capture registers. TGRC and TGRD for MTU0, MTU3, MTU4, MTU6, and MTU7 can also be designated for operation as buffer registers. TGR buffer register combinations are TGRA and TGRC, and TGRB and TGRD.

MTU0.TGRE and MTU0.TGRF function as compare registers. When the MTU0.TCNT count matches the MTU0.TGRE value, an A/D converter start request can be issued. TGRF can also be designated for operation as a buffer register. TGR buffer register combination is TGRE and TGRF.

MTU5.TGRU, MTU5.TGRV, and MTU5.TGRW function as compare match, input capture, or external pulse width measurement registers.

16.2.13 Timer Start Register (TSTR)

- TSTRA (MTU0 to MTU4)

Address: 000C 1280h

	b7	b6	b5	b4	b3	b2	b1	b0
	CST4	CST3	—	—	—	CST2	CST1	CST0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	CST0	Counter Start 0	0: MTU0.TCNT count operation is stopped 1: MTU0.TCNT performs count operation	R/W
b1	CST1	Counter Start 1	0: MTU1.TCNT count operation is stopped 1: MTU1.TCNT performs count operation	R/W
b2	CST2	Counter Start 2	0: MTU2.TCNT count operation is stopped 1: MTU2.TCNT performs count operation	R/W
b5 to b3	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W
b6	CST3	Counter Start 3	0: MTU3.TCNT count operation is stopped 1: MTU3.TCNT performs count operation	R/W
b7	CST4	Counter Start 4	0: MTU4.TCNT count operation is stopped 1: MTU4.TCNT performs count operation	R/W

Note 1. When 1 is written to a bit in TCSYSTR, the corresponding bit in TSTRA is also set to 1 automatically.

TSTRA starts or stops TCNT operation in MTU0 to MTU4.
TSTRB starts or stops TCNT operation in MTU6 and MTU7.
TSTR starts or stops TCNT operation in MTU5.
Before setting the operating mode in TMDR1 or setting the TCNT count clock in TCR, be sure to stop the TCNT counter.

CSTn Bits (Counter Start n; n = 0 to 4)

Each bit starts or stops TCNT in the corresponding channel.
If 0 is written to the CSTn bit during operation with the MTIOC pin designated for output, the counter stops but the output compare signal level from the MTIOC pin is retained. If TIOR is written to while the CSTn bit is 0, the pin output level will be changed to the specified initial output value.

- TSTRB (MTU6, MTU7)

Address: 000C 1A80h

	b7	b6	b5	b4	b3	b2	b1	b0
	CST7	CST6	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b5 to b0	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W
b6	CST6	Counter Start 6	0: MTU6.TCNT count operation is stopped 1: MTU6.TCNT performs count operation	R/W
b7	CST7	Counter Start 7	0: MTU7.TCNT count operation is stopped 1: MTU7.TCNT performs count operation	R/W

Note 1. When 1 is written to a bit in TCSYSTR, the corresponding bit in TSTRB is also set to 1 automatically.

CSTn Bits (Counter Start n) (n = 6 or 7)
Each bit starts or stops TCNT in the corresponding channel.
If 0 is written to the CSTn bit during operation with the MTIOC pin designated for output, the counter stops but the output compare signal level from the MTIOC pin is retained. If TIOR is written to while the CSTn bit is 0, the pin output level will be changed to the specified initial output value.

- TSTR (MTU5)

Address: 000C 1CB4h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	CSTU5	CSTV5	CSTW5
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	CSTW5	Counter Start W5	0: MTU5.TCNTW count operation is stopped 1: MTU5.TCNTW performs count operation	R/W
b1	CSTV5	Counter Start V5	0: MTU5.TCNTV count operation is stopped 1: MTU5.TCNTV performs count operation	R/W
b2	CSTU5	Counter Start U5	0: MTU5.TCNTU count operation is stopped 1: MTU5.TCNTU performs count operation	R/W
b7 to b3	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W

CSTn5 Bits (Counter Start n5; n = U, V, W)

These bits cause the respective TCNT registers to stop or run.

16.2.14 Timer Synchronous Register (TSYR)

- TSYRA (MTU0 to MTU4)

Address: MTU.TSYRA 000C 1281h

	b7	b6	b5	b4	b3	b2	b1	b0
	SYNC4	SYNC3	—	—	—	SYNC2	SYNC1	SYNC0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	SYNC0	Timer Synchronous Operation 0	0: MTU0.TCNT operates independently (TCNT presetting/clearing is not related to other channels). 1: MTU0.TCNT performs synchronous operation. (TCNT synchronous presetting/synchronous clearing is enabled.)	R/W
b1	SYNC1	Timer Synchronous Operation 1	0: MTU1.TCNT operates independently (TCNT presetting/clearing is not related to other channels). 1: MTU1.TCNT performs synchronous operation. (TCNT synchronous presetting/synchronous clearing is enabled.)	R/W
b2	SYNC2	Timer Synchronous Operation 2	0: MTU2.TCNT operates independently (TCNT presetting/clearing is not related to other channels). 1: MTU2.TCNT performs synchronous operation. (TCNT synchronous presetting/synchronous clearing is enabled.)	R/W
b5 to b3	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W
b6	SYNC3	Timer Synchronous Operation 3	0: MTU3.TCNT operates independently (TCNT presetting/clearing is not related to other channels). 1: MTU3.TCNT performs synchronous operation. (TCNT synchronous presetting/synchronous clearing is enabled.)	R/W
b7	SYNC4	Timer Synchronous Operation 4	0: MTU4.TCNT operates independently (TCNT presetting/clearing is not related to other channels). 1: MTU4.TCNT performs synchronous operation. (TCNT synchronous presetting/synchronous clearing is enabled.)	R/W

TSYRA selects independent operation or synchronous operation of TCNT in MTU0 to MTU4.
TSYRB selects independent operation or synchronous operation of TCNT in MTU6 and MTU7.
A channel performs synchronous operation when the corresponding bit in TSYR is set to 1.

SYNCn Bits (Timer Synchronous Operation n; n = 0, 1, 2, 3, and 4)

Each bit selects whether operation is independent of or synchronized with other channels.
When synchronous operation is selected, the TCNT synchronous presetting of multiple channels and synchronous clearing by counter clearing on another channel are possible.
To set synchronous operation, the SYNC bits for at least two channels must be set to 1. To set synchronous clearing, in addition to the SYNC bit, the TCNT clearing source must also be set by means of bits TCR.CCLR[2:0].

- TSYRB (MTU6, MTU7)

Address: MTU.TSYRB 000C 1A81h

	b7	b6	b5	b4	b3	b2	b1	b0
	SYNC7	SYNC6	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b5 to b0	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W
b6	SYNC6	Timer Synchronous Operation 6	0: MTU6.TCNT operates independently (TCNT presetting/clearing is not related to other channels). 1: MTU6.TCNT performs synchronous operation. (TCNT synchronous presetting/synchronous clearing is enabled.)	R/W
b7	SYNC7	Timer Synchronous Operation 7	0: MTU7.TCNT operates independently (TCNT presetting/clearing is not related to other channels). 1: MTU7.TCNT performs synchronous operation. (TCNT synchronous presetting/synchronous clearing is enabled.)	R/W

SYNCn Bits (Timer Synchronous Operation n; n = 6 or 7)

Each bit selects whether operation is independent of or synchronized with other channels.

When synchronous operation is selected, the TCNT synchronous presetting of multiple channels and synchronous clearing by counter clearing on another channel are possible.

To set synchronous operation, the SYNC bits for at least two channels must be set to 1. To set synchronous clearing, in addition to the SYNC bit, the TCNT clearing source must also be set by means of bits TCR.CCLR[2:0].

16.2.15 Timer Counter Synchronous Start Register (TCSYSTR)

Address: 000C 1282h

	b7	b6	b5	b4	b3	b2	b1	b0
	SCH0	SCH1	SCH2	SCH3	SCH4	—	SCH6	SCH7
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	SCH7	Synchronous Start 7	0: Does not specify synchronous start for MTU7.TCNT 1: Specifies synchronous start for MTU7.TCNT	R/(W)*1
b1	SCH6	Synchronous Start 6	0: Does not specify synchronous start for MTU6.TCNT 1: Specifies synchronous start for MTU6.TCNT	R/(W)*1
b2	—	Reserved	This bit is always read as 0. The write value should be 0.	R
b3	SCH4	Synchronous Start 4	0: Does not specify synchronous start for MTU4.TCNT 1: Specifies synchronous start for MTU4.TCNT	R/(W)*1
b4	SCH3	Synchronous Start 3	0: Does not specify synchronous start for MTU3.TCNT 1: Specifies synchronous start for MTU3.TCNT	R/(W)*1
b5	SCH2	Synchronous Start 2	0: Does not specify synchronous start for MTU2.TCNT 1: Specifies synchronous start for MTU2.TCNT	R/(W)*1
b6	SCH1	Synchronous Start 1	0: Does not specify synchronous start for MTU1.TCNT 1: Specifies synchronous start for MTU1.TCNT	R/(W)*1
b7	SCH0	Synchronous Start 0	0: Does not specify synchronous start for MTU0.TCNT 1: Specifies synchronous start for MTU0.TCNT	R/(W)*1

Note 1. Only 1 can be written to clear the flag.
TCSYSTR is automatically cleared after 1 is written to.

TCSYSTR specifies synchronous start of the counters.

SCH7 Bit (Timer Start 7)

This bit controls synchronous start of MTU7.TCNT.

[Clearing condition]

- When 1 is set to the TSTRA.CST7 bit while SCH7 = 1

SCH6 Bit (Timer Start 6)

This bit controls synchronous start of MTU6.TCNT.

[Clearing condition]

- When 1 is set to the TSTRA.CST6 bit while SCH6 = 1

SCH4 Bit (Timer Start 4)

This bit controls synchronous start of MTU4.TCNT.

[Clearing condition]

- When 1 is set to the TSTRA.CST4 bit while SCH4 = 1

SCH3 Bit (Timer Start 3)

This bit controls synchronous start of MTU3.TCNT.

[Clearing condition]

- When 1 is set to the TSTRA.CST3 bit while SCH3 = 1

SCH2 Bit (Timer Start 2)

This bit controls synchronous start of MTU2.TCNT.
[Clearing condition]

- When 1 is set to the TSTRA.CST2 bit while SCH2 = 1

SCH1 Bit (Timer Start 1)

This bit controls synchronous start of MTU1.TCNT.
[Clearing condition]

- When 1 is set to the TSTRA.CST1 bit while SCH1 = 1

SCH0 Bit (Timer Start 0)

This bit controls synchronous start of MTU0.TCNT.
[Clearing condition]

- When 1 is set to the TSTRA.CST0 bit while SCH0 = 1

16.2.16 Timer Read/Write Enable Registers (TRWERA and TRWERB)

Address: TRWERA 000C 1284h, TRWERB 000C 1A84h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	RWE
Value after reset:	0	0	0	0	0	0	0	1

Bit	Symbol	Bit Name	Description	R/W
b0	RWE	Read/Write Enable	0: Read/write access to the registers is disabled 1: Read/write access to the registers is enabled	R/W
b7 to b1	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W

TRWERA enables or disables access to the registers and counters that have write-protection capability against accidental modification in MTU3 and MTU4.
TRWERB enables or disables access to the registers and counters that have write-protection capability against accidental modification in MTU6 and MTU7.

RWE Bit (Read/Write Enable)

This bit enables or disables access to the registers that have write-protection capability against accidental modification.
[Clearing condition]

- When 0 is written to the RWE bit after reading RWE = 1

- Registers and Counters having Write-Protection Capability against Accidental Modification (TRWERA)
  22 registers: MTUn.TCR, MTUn.TMDR1, MTUn.TIORH, MTUn.TIORL, MTUn.TIER, MTUn.TGRA, MTUn.TGRB, TOERA, TOCR1A, TOCR2A, TGCRA, TCDRA, TDDRA, and MTUn.TCNT (n = 3 or 4)
- Registers and Counters having Write-Protection Capability against Accidental Modification (TRWERB)
  21 registers: MTUn.TCR, MTUn.TMDR1, MTUn.TIORH, MTUn.TIORL, MTUn.TIER, MTUn.TGRA, MTUn.TGRB, TOERB, TOCR1B, TOCR2B, TCDRB, TDDRB, and MTUn.TCNT (n = 6 or 7)

16.2.17 Timer Output Master Enable Register (TOER)

- TOERA

Address: 000C 120Ah

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	OE4D	OE4C	OE3D	OE4B	OE4A	OE3B
Value after reset:	1	1	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	OE3B	Master Enable MTIOC3B	0: MTU3 output is disabled *1 1: MTU3 output is enabled	R/W
b1	OE4A	Master Enable MTIOC4A	0: MTU3 output is disabled *1 1: MTU3 output is enabled	R/W
b2	OE4B	Master Enable MTIOC4B	0: MTU3 output is disabled *1 1: MTU3 output is enabled	R/W
b3	OE3D	Master Enable MTIOC3D	0: MTU3 output is disabled *1 1: MTU3 output is enabled	R/W
b4	OE4C	Master Enable MTIOC4C	0: MTU3 output is disabled *1 1: MTU3 output is enabled	R/W
b5	OE4D	Master Enable MTIOC4D	0: MTU3 output is disabled *1 1: MTU3 output is enabled	R/W
b7, b6	—	Reserved	These bits are always read as 1. The write value should be 1.	R/W

Note 1. To output a non-active level from each pin when MTU3 output is disabled, make necessary settings for non-active level output from general I/O ports in the data direction registers (DDR) and data registers (DR) in advance. For details, refer to section 15, I/O Ports.

TOERA enables or disables output settings for output pins MTIOC4D, MTIOC4C, MTIOC3D, MTIOC4B, MTIOC4A, and MTIOC3B.
TOERB enables or disables output settings for output pins MTIOC7D, MTIOC7C, MTIOC6D, MTIOC7B, MTIOC7A, and MTIOC6B.
These pins do not output correctly if the TOER bits have not been set. In MTU3, MTU4, MTU6, and MTU7, set TOER prior to setting TIOR.
Set the MTU.TOERA register after the CST3 and CST4 bits in the MTU.TSTRA register have been cleared to 0.
Set the MTU.TOERB register after the CST0 and CST1 bits in the MTU.TSTRB register have been cleared to 0 (refer to Figure 16.36 and Figure 16.39).

OEnm Bits (Master Enable MTIOCnm; n = 3 or 4, m = A to D)

These bits enable or disable the output setting for MTIOCnm output pin of MTU3.

- TOERB

Address: 000C 1A0Ah

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	OE7D	OE7C	OE6D	OE7B	OE7A	OE6B
Value after reset:	1	1	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	OE6B	Master Enable MTIOC6B	0: MTU3 output is disabled*1 1: MTU3 output is enabled	R/W
b1	OE7A	Master Enable MTIOC7A	0: MTU3 output is disabled*1 1: MTU3 output is enabled	R/W
b2	OE7B	Master Enable MTIOC7B	0: MTU3 output is disabled*1 1: MTU3 output is enabled	R/W
b3	OE6D	Master Enable MTIOC6D	0: MTU3 output is disabled*1 1: MTU3 output is enabled	R/W
b4	OE7C	Master Enable MTIOC7C	0: MTU3 output is disabled*1 1: MTU3 output is enabled	R/W
b5	OE7D	Master Enable MTIOC7D	0: MTU3 output is disabled*1 1: MTU3 output is enabled	R/W
b7, b6	—	Reserved	These bits are always read as 1. The write value should be 1.	R/W

Note 1. To output a non-active level from each pin when MTU3 output is disabled, make necessary settings for non-active level output from general I/O ports in the data direction registers (DDR) and data registers (DR) in advance. For details, refer to section 15, I/O Ports.

OEnm Bits (Master Enable MTIOCnm; n = 6 or 7, m = A to D)

These bits enable or disable the output setting for MTIOCnm output pin of MTU3.

16.2.18 Timer Output Control Registers 1 (TOCR1A and TOCR1B)

Address: TOCR1A 000C 120Eh, TOCR1B 000C 1A0Eh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	PSYE	—	—	TOCL	TOCS	OLSN	OLSP
Value after reset:	0	0	0	0	0*1	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	OLSP	Output Level Select P*1, *3	See Table 16.38.	R/W
b1	OLSN	Output Level Select N*1, *3	See Table 16.39.	R/W
b2	TOCS	TOC Select	0: TOCR1j setting is selected (j = A or B) 1: TOCR2j setting is selected	R/W
b3	TOCL	TOC Register Write Protection*4	0: Write access to the TOCS, OLSN, and OLSP bits is enabled 1: Write access to the TOCS, OLSN, and OLSP bits is disabled	R/W
b5, b4	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W
b6	PSYE	PWM Synchronous Output Enable	0: Toggle output is disabled 1: Toggle output is enabled	R/W
b7	—	Reserved	This bit is always read as 0. The write value should be 0.	R/W

Note 1. Setting the TOCR1j.TOCL bit to 1 prevents accidental modification when the CPU goes out of control.
Note 2. Clearing the TOCR1j.TOCS bit to 0 makes this bit setting valid.
Note 3. If dead time is not generated, the negative-phase output is always the exact inverse of the positive-phase output. In this case, only the OLSP bit is effective.
Note 4. This bit can be set to 1 only once after a reset. After 1 is written, 0 cannot be written to the bit.

TOCR1A and TOCR1B enable or disable PWM-synchronized toggle output in complementary PWM mode and reset-synchronized PWM mode, and control inversion of PWM output level.

OLSP Bit (Output Level Select P)

This bit selects the positive-phase output level in reset-synchronized PWM mode and complementary PWM mode.

OLSN Bit (Output Level Select N)

This bit selects the negative-phase output level in reset-synchronized PWM mode and complementary PWM mode.

TOCS Bit (TOC Select)

This bit selects either the TOCR1j or TOCR2j (j = A or B) setting to be used for the output level in complementary PWM mode and reset-synchronized PWM mode.

TOCL Bit (TOC Register Write Protection)

This bit enables or disables write access to the TOCS, OLSN, and OLSP bits in TOCR1j (j = A or B).

PSYE Bit (PWM Synchronous Output Enable)

This bit enables or disables toggle output synchronized with the PWM cycle.

Table 16.38 Output Level Select Function

Bit 0			Function	
			Compare Match Output	
OLSP	Initial Output	Active Level	Up-Counting	Down-Counting
0	High level	Low level	Low level	High level
1	Low level	High level	High level	Low level

Table 16.39 Output Level Select Function

Bit 1			Function	
			Compare Match Output	
OLSN	Initial Output	Active Level	Up-Counting	Down-Counting
0	High level	Low level	High level	Low level
1	Low level	High level	Low level	High level

Note: • The initial output value of negative-phase waveform changes to an active level after the dead time has passed since counting starts.

Figure 16.3 shows an example of output in complementary PWM mode (one phase) when OLSN = 1 and OLSP = 1.

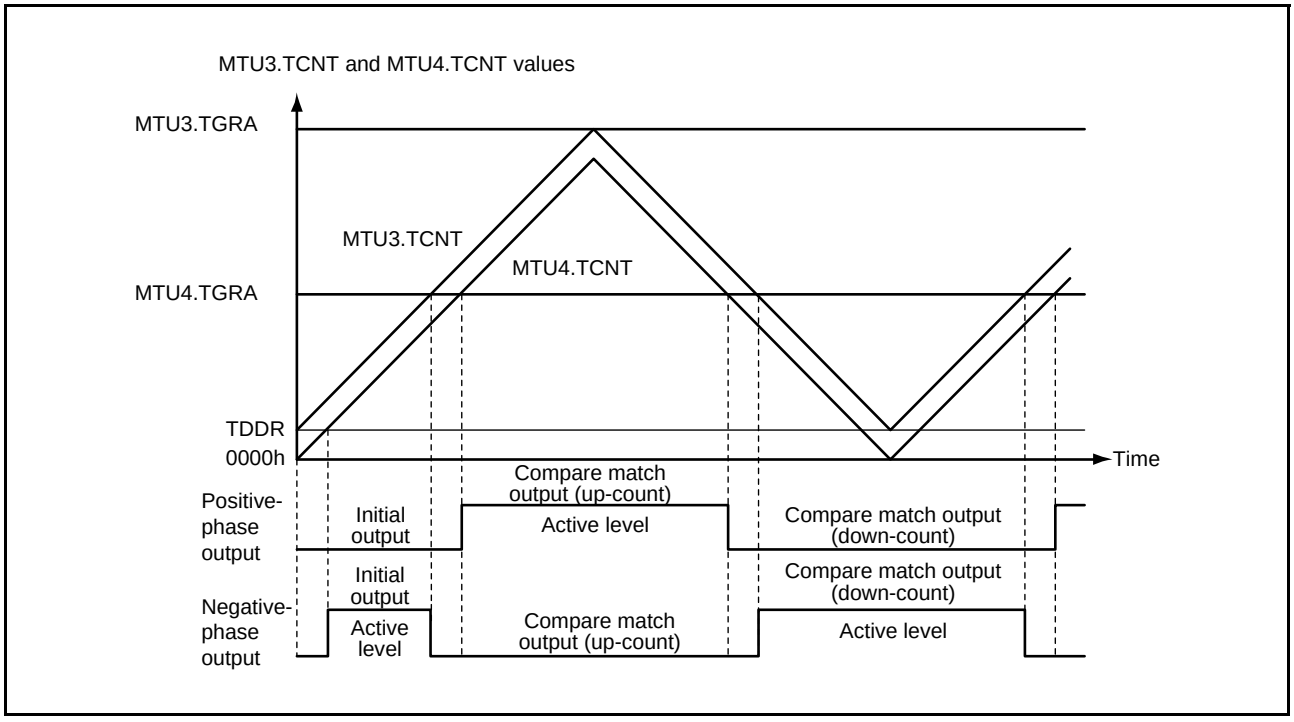


Figure 16.3 Example of Output in Complementary PWM Mode

16.2.19 Timer Output Control Registers 2 (TOCR2A and TOCR2B)

Address: TOCR2A 000C 120Fh, TOCR2B 000C 1A0Fh

	b7	b6	b5	b4	b3	b2	b1	b0
	BF[1:0]		OLS3N	OLS3P	OLS2N	OLS2P	OLS1N	OLS1P
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	OLS1P	Output Level Select 1P*1, *2	This bit selects the output level on MTIOC3B or MTIOC6B in reset-synchronized PWM mode and complementary PWM mode. See Table 16.40.	R/W
b1	OLS1N	Output Level Select 1N*1, *2	This bit selects the output level on MTIOC3D or MTIOC6D in reset-synchronized PWM mode and complementary PWM mode. See Table 16.41.	R/W
b2	OLS2P	Output Level Select 2P*1, *2	This bit selects the output level on MTIOC4A or MTIOC7Ain reset-synchronized PWM mode and complementary PWM mode. See Table 16.42.	R/W
b3	OLS2N	Output Level Select 2N*1, *2	This bit selects the output level on MTIOC4C or MTIOC7C in reset-synchronized PWM mode and complementary PWM mode. See Table 16.43.	R/W
b4	OLS3P	Output Level Select 3P*1, *2	This bit selects the output level on MTIOC4B or MTIOC7B in reset-synchronized PWM mode and complementary PWM mode. See Table 16.44.	R/W
b5	OLS3N	Output Level Select 3N*1, *2	This bit selects the output level on MTIOC4D or MTIOC7D in reset-synchronized PWM mode and complementary PWM mode. See Table 16.45.	R/W
b7, b6	BF[1:0]	TOLBR Buffer Transfer Timing Select	These bits select the timing for transferring data from TOLBRj to TOCR2j. See Table 16.46 for details.	R/W

j = A or B

Note 1. Setting the TOCR1j.TOCS bit to 1 makes this bit setting valid.

Note 2. If dead time is not generated, the negative-phase output is always the exact inverse of the positive-phase output. In this case, only the OLSiP bit is effective (i = 1, 2, 3).

TOCR2A and TOCR2B control inversion of PWM output level in complementary PWM mode and reset-synchronized PWM mode.

Table 16.40 MTIOCmB Output Level Select Function

Bit 0	Function			
			Compare Match Output	
OLS1P	Initial Output	Active Level	Up-Counting	Down-Counting
0	High level	Low level	Low level	High level
1	Low level	High level	High level	Low level

m = 3 or 6

Table 16.41 MTIOCmD Output Level Select Function

Bit 1	Function			
			Compare Match Output	
OLS1N	Initial Output	Active Level	Up-Counting	Down-Counting
0	High level	Low level	High level	Low level
1	Low level	High level	Low level	High level

m = 3 or 6

Note: • The initial output value of negative-phase waveform changes to an active level after the dead time has passed since counting starts.

Table 16.42 MTIOCmA Output Level Select Function

Bit 2	Function			
			Compare Match Output	
OLS2P	Initial Output	Active Level	Up-Counting	Down-Counting
0	High level	Low level	Low level	High level
1	Low level	High level	High level	Low level

m = 4 or 7

Table 16.43 MTIOCmC Output Level Select Function

Bit 3	Function			
			Compare Match Output	
OLS2N	Initial Output	Active Level	Up-Counting	Down-Counting
0	High level	Low level	High level	Low level
1	Low level	High level	Low level	High level

m = 4 or 7

Note: • The initial output value of negative-phase waveform changes to an active level after the dead time has passed since counting starts.

Table 16.44 MTIOCmB Output Level Select Function

Bit 4	Function			
			Compare Match Output	
OLS3P	Initial Output	Active Level	Up-Counting	Down-Counting
0	High level	Low level	Low level	High level
1	Low level	High level	High level	Low level

m = 4 or 7

Table 16.45 MTIOCmD Output Level Select Function

Bit 5	Function			
			Compare Match Output	
OLS3N	Initial Output	Active Level	Up-Counting	Down-Counting
0	High level	Low level	High level	Low level
1	Low level	High level	Low level	High level

m = 4 or 7

Note: • The initial output value of negative-phase waveform changes to an active level after the dead time has passed since counting starts.

Table 16.46 Setting of TOCR2j.BF[1:0] Bits

Bit 7	Bit 6	Description	
BF1	BF0	Complementary PWM Mode	Reset-Synchronized PWM Mode
0	0	Does not transfer data from the buffer register (TOLBRj) to TOCR2j.	Does not transfer data from the buffer register (TOLBRj) to TOCR2j.
0	1	Transfers data from the buffer register (TOLBRj) to TOCR2j at the crest of the MTUn.TCNT count.	Transfers data from the buffer register (TOLBRj) to TOCR2j when MTUm.TCNT or MTUn.TCNT is cleared.
1	0	Transfers data from the buffer register (TOLBRj) to TOCR2j at the trough of the MTUn.TCNT count.	Setting prohibited
1	1	Transfers data from the buffer register (TOLBRj) to TOCR2j at the crest and trough of the MTUn.TCNT count.	Setting prohibited

n = 4 or 7, m = 3 or 6, j = A or B

16.2.20 Timer Output Level Buffer Registers (TOLBRA and TOLBRB)

Address: TOLBRA 000C 1236h, TOLBRB 000C 1A36h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	OLS3N	OLS3P	OLS2N	OLS2P	OLS1N	OLS1P
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	OLS1P	Output Level Select 1P	Specify the buffer value to be transferred to the OLS1P bit in TOCR2j.	R/W
b1	OLS1N	Output Level Select 1N	Specify the buffer value to be transferred to the OLS1N bit in TOCR2j.	R/W
b2	OLS2P	Output Level Select 2P	Specify the buffer value to be transferred to the OLS2P bit in TOCR2j.	R/W
b3	OLS2N	Output Level Select 2N	Specify the buffer value to be transferred to the OLS2N bit in TOCR2j.	R/W
b4	OLS3P	Output Level Select 3P	Specify the buffer value to be transferred to the OLS3P bit in TOCR2j.	R/W
b5	OLS3N	Output Level Select 3N	Specify the buffer value to be transferred to the OLS3N bit in TOCR2j.	R/W
b7, b6	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W

j = A or B

TOLBRA and TOLBRB are buffer registers for TOCR2A and TOCR2B and specify the PWM output level in complementary PWM mode and reset-synchronized PWM mode.

Figure 16.4 shows an example of the PWM output level setting procedure in buffer operation.

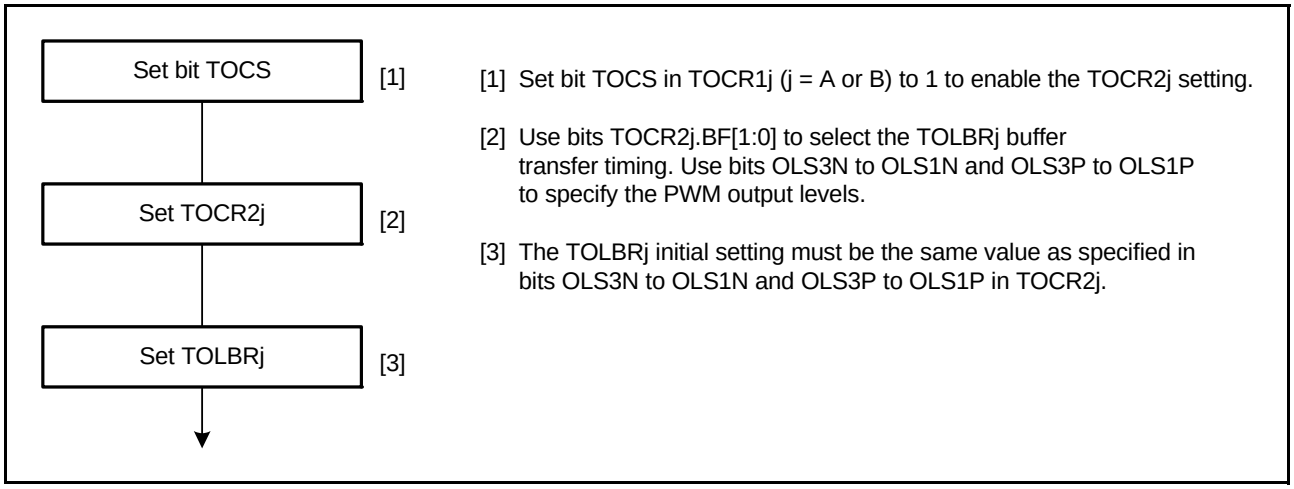


Figure 16.4 Example of PWM Output Level Setting Procedure in Buffer Operation

16.2.21 Timer Gate Control Register A (TGCRA)

Address: 000C 120Dh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	BDC	N	P	FB	WF	VF	UF
Value after reset:	1	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	UF	Output Phase Switch	These bits turn on or off the positive-phase/negative-phase output. The setting of these bits is valid only when the TGCR.FB bit s set to 1. In this case, the setting of b0 to b2 is used instead of the external input. See Table 16.47.	R/W
b1	VF			R/W
b2	WF			R/W
b3	FB	External Feedback Signal Enable	0: Output is switched by external input (input sources are TGRA, TGRB, and TGRC input capture signals in MTU0) 1: Output is switched by software (TGCRA's UF, VF, and WF settings)	R/W
b4	P	Positive-Phase Output (P) Control	0: Level output 1: Reset-synchronized PWM or complementary PWM output	R/W
b5	N	Negative-Phase Output (N) Control	0: Level output 1: Reset-synchronized PWM or complementary PWM output	R/W
b6	BDC	Brushless DC Motor	0: Ordinary output 1: Functions of this register are made effective	R/W
b7	—	Reserved	This bit is always read as 1. The write value should be 1.	R/W

TGCRA controls the output waveform necessary for brushless DC motor control in reset-synchronized PWM mode and complementary PWM mode. TGCRA register settings are ineffective for anything other than complementary PWM mode and reset-synchronized PWM mode.

UF, VF, and WF Bits (Output Phase Switch)

These bits are used to switch output of the positive- and negative-phase signals on or off.

FB Bit (External Feedback Signal Enable)

This bit selects whether the positive-/negative-phase output is switched automatically with the TGRA, TGRB, and TGRC input capture signals in MTU0 or by writing 0 or 1 to bits 2 to 0 in TGCRA.

P Bit (Positive-Phase Output (P) Control)

This bit selects the level output or the reset-synchronized PWM/complementary PWM output for the positive-phase output pins (MTIOC3B, MTIOC4A, and MTIOC4B pins).

N Bit (Negative-Phase Output (N) Control)

This bit selects the level output or the reset-synchronized PWM/complementary PWM output for the negative-phase output pins (MTIOC3D, MTIOC4C, and MTIOC4D pins).

BDC Bit (Brushless DC Motor)

This bit selects whether to make the functions of TGCRA effective or ineffective.

Table 16.47 Output Level Select Function

Bit 2	Bit 1	Bit 0	Function					
			MTIOC3B	MTIOC4A	MTIOC4B	MTIOC3D	MTIOC4C	MTIOC4D
WF	VF	UF	U Phase	V Phase	W Phase	U Phase	V Phase	W Phase
0	0	0	OFF	OFF	OFF	OFF	OFF	OFF
0	0	1	ON	OFF	OFF	OFF	OFF	ON
0	1	0	OFF	ON	OFF	ON	OFF	OFF
0	1	1	OFF	ON	OFF	OFF	OFF	ON
1	0	0	OFF	OFF	ON	OFF	ON	OFF
1	0	1	ON	OFF	OFF	OFF	ON	OFF
1	1	0	OFF	OFF	ON	ON	OFF	OFF
1	1	1	OFF	OFF	OFF	OFF	OFF	OFF

16.2.22 Timer Subcounters (TCNTSA and TCNTSB)

Address: TCNTSA 000C 1220h, TCNTSB 000C 1A20h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Note 1. TCNTSA and TCNTSB must not be accessed in eight bits; it should always be accessed in 16 bits.

TCNTSA and TCNTSB are 16-bit read-only counters that are used only in complementary PWM mode.
The initial value of TCNTSA and TCNTSB after a reset is 0000h.

16.2.23 Timer Cycle Data Registers (TCDRA and TCDRB)

Address: TCDRA 000C 1214h, TCDRB 000C 1A14h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Note 1. TCDRA and TCDRB must not be accessed in eight bits; it should always be accessed in 16 bits.

TCDRA and TCDRB are 16-bit readable/writable registers

registers used only in complementary PWM mode. Set half the PWM carrier cycle as the TCDRA and TCDRB values.
The initial value of TCDRA and TCDRB after a reset is FFFFh.

16.2.24 Timer Cycle Buffer Registers (TCBRA and TCBRB)

Address: TCBRA 000C 1222h, TCBRB 000C 1A22h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Note 1. TCBR must not be accessed in eight bits; it should always be accessed in 16 bits.

TCBRA and TCBRB are 16-bit readable/writable registers, used only in complementary PWM mode, that function as buffer registers for TCDRA and TCDRB. The TCBRA and TCBRB values are transferred to TCDRA and TCDRB with the transfer timing set in TMDR1. The initial value of TCBRA and TCBRB after a reset is FFFFh.

16.2.25 Timer Dead Time Data Registers (TDDRA and TDDRB)

Address: TDDRA 000C 1216h, TDDRB 000C 1A16h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Note 1. TDDR must not be accessed in eight bits; it should always be accessed in 16 bits.

TDDRA and TDDRB are 16-bit readable/writable registers, used only in complementary PWM mode, that specify the MTU3.TCNT (MTU6.TCNT) and MTU4.TCNT (MTU7.TCNT) counter offset value. In complementary PWM mode, when the MTU3.TCNT (MTU6.TCNT) and MTU4.TCNT (MTU7.TCNT) counters are cleared and then restarted, the TDDRA (TDDRB) value is loaded into the MTU3.TCNT (MTU6.TCNT) counter and the count operation starts. The initial value of TDDRA and TDDRB after a reset is FFFFh.

16.2.26 Timer Dead Time Enable Registers (TDERA and TDERB)

Address: MTU3.TDERA 000C 1234h, MTU6.TDERB 000C 1A34h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	TDER
Value after reset:	0	0	0	0	0	0	0	1

Bit	Symbol	Bit Name	Description	R/W
b0	TDER	Dead Time Enable	0: No dead time is generated 1: Dead time is generated *1	R/(W)
b7 to b1	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W

Note 1. TDDRA and TDDRB must be set to 1 or a larger value.

TDERA and TDERB control dead time generation in complementary PWM mode. The MTU3 has one TDER each for MTU3 and MTU6. TDERA and TDERB should be modified only while TCNT stops.

TDER Bit (Dead Time Enable)

This bit specifies whether to generate dead time.

[Clearing condition]

When 0 is written to TDER after reading TDER = 1

16.2.27 Timer Buffer Transfer Set Registers (TBTERA and TBTERB)

Address: TBTERA 000C 1232h, TBTERB 000C 1A32h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	BTE[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1 to b0	BTE[1:0]	Buffer Transfer Disable and Interrupt Skipping Link Setting	These bits enable or disable transfer from the buffer registers*1 used in complementary PWM mode to the temporary registers, and specify whether to link the transfer with interrupt skipping function 1. For details, see Table 16.48.	R/W
b7 to b2	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W

Note 1. Applicable buffer registers (TBTERA):
MTU3.TGRC, MTU3.TGRD, MTU4.TGRC, MTU4.TGRD, and TCBRA
Applicable buffer registers (TBTER_B):
MTU6.TGRC, MTU6.TGRD, MTU7.TGRC, MTU7.TGRD, and TCBRB

TBTERA and TBTERB enable or disable transfer from the buffer registers used in complementary PWM mode to the temporary registers, and specify whether to link the transfer with interrupt skipping 1 operation.

Table 16.48 Setting of TBTER.BTE[1:0] Bits

Bit 1	Bit 0	
BTE1	**BTE0**	**Description**
0	0	Enables transfer from the buffer registers to the temporary registers*1 and does not link the transfer with interrupt skipping function 1.
0	1	Disables transfer from the buffer registers to the temporary registers.
1	0	Links transfer from the buffer registers to the temporary registers with interrupt skipping function 1.*2
1	1	Setting prohibited

Note 1. Data is transferred according to the MD3 to MD0 bit setting in TMDR1. For details, refer to section 16.3.8, Complementary PWM Mode .

Note 2. When interrupt skipping is disabled (the T3AEN and T4VEN (T6AEN and T7VEN) bits are cleared to 0 in the timer interrupt skipping set register (TITCR1A (TITCR1B)) or the skipping count set bits (T3ACOR and T4VCOR (T6ACOR and T7VCOR)) in TITCR1A (TITCR1B) are cleared to 0), be sure to disable link of buffer transfer with interrupt skipping (clear the BTE1 bit in the timer buffer transfer set register (TBTERA (TBTERB)) to 0). If link with interrupt skipping is enabled while interrupt skipping is disabled, buffer transfer will not be performed.

16.2.28 Timer Waveform Control Registers (TWCRA and TWCRB)

Address: TWCRA 000C 1260h, TWCRB 000C 1A60h

	b7	b6	b5	b4	b3	b2	b1	b0
	CCE	—	—	—	—	—	SCC	WRE
Value after reset:	0*2	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	WRE	Waveform Retain Enable	0: Initial values specified in TOCR1A and TOCR2A (TOCR1B and TOCR2B) are output 1: Initial output is inhibited	R/(W)
b1	SCC*1	Synchronous Clearing Control	(Only valid in register TWCRB) 0: Clearing of MTU6.TCNT and MTU7.TCNT in response to synchronous clearing for MTU0, MTU1, MTU2 - MTU6, MTU7 is enabled. 1: Clearing of MTU6.TCNT and MTU7.TCNT in response to synchronous clearing for MTU0, MTU1, MTU2 - MTU6, MTU7 is disabled.	R/(W)
b6 to b2	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W
b7	CCE*2	Compare Match Clear Enable	0: Counters are not cleared at MTU3.TGRA (MTU6.TGRA) compare match 1: Counters are cleared at MTU3.TGRA (MTU6.TGRA) compare match	R/(W)

Note 1. This bit is only valid in register TWCRB and is a reserved bit in register TWCRA.
Note 2. Do not write 1 to this bit unless complementary PWM mode is selected.

TWCRA and TWCRB control the output waveform when synchronous counter clearing occurs in MTU3.TCNT and MTU4.TCNT (MTU6.TCNT and MTU7.TCNT) in complementary PWM mode and specifies whether to clear the counters at MTU3.TGRA (MTU6.TGRA) compare match.
The CCE bit and WRE bit in TWCRA and TWCRB should be modified only while TCNT stops.

WRE Bit (Waveform Retain Enable)

This bit selects the waveform output when synchronous counter clearing occurs in complementary PWM mode.
The initial output is inhibited with this function only when synchronous clearing occurs within the Tb interval at the trough in complementary PWM mode. When synchronous clearing occurs outside this interval, the initial values specified in TOCR1A and TOCR2A (TOCR1B and TOCR2B) are output regardless of the WRE bit setting. The initial values specified in TOCR1A and TOCR2A (TOCR1B and TOCR2B) are also output when synchronous clearing occurs in the Tb interval at the trough immediately after MTU3.TCNT and MTU4.TCNT (MTU6.TCNT and MTU7.TCNT) start operation.
For the Tb interval at the trough in complementary PWM mode, see Figure 16.41.
[Setting condition]

- When 1 is written to TWCR.WRE after reading TWCR.WRE = 0

SCC Bit (Synchronous Clearing Control) (Only valid in register TWCRB)

The setting of this bit selects whether MTU6.TCNT and MTU7.TCNT are or are not cleared when counter-synchronous clearing is generated for MTU0, MTU1, MTU2 - MTU6, MTU7 in complementary PWM mode.
Make the complementary PWM mode settings for MTU6 and MTU7 when this function is in use. When writing a new value to the SCC bit while the counter is operating, do so in such a way that the values of the CCE and WRE bits are not changed.
Synchronous clearing from the MTU3 module only becomes disabled due to the setting of the SCC bit when synchronous clearing is generated outside the Tb interval in the trough. If synchronous clearing is generated within the Tb interval in the trough including immediately after the value at which MTU6.TCNT and MTU7.TCNT start, MTU6.TCNT and MTU7.TCNT are cleared.
Regarding the Tb interval in the trough in complementary PWM mode, see Figure 16.41.
[Setting condition]

- Writing of 1 to the SCC bit after reading it as 0

The corresponding bit in register TWCRA is reserved and is always read as 0. When writing to TWCRA, always write 0 to this bit.

CCE Bit (Compare Match Clear Enable)

This bit specifies whether to clear counters at MTU3.TGRA (MTU6.TGRA) compare match in complementary PWM mode.
[Setting condition]

- When 1 is written to CCE after reading CCE = 0

16.2.29 Timer A/D Converter Start Request Control Register (TADCR)

- TADCR (MTU4)

Address: 000C 1240h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	BF[1:0]		—	—	—	—	—	—	UT4AE	DT4AE	UT4BE	DT4BE	ITA3AE	ITA4VE	ITB3AE	ITB4VE
Value after reset:	0	0	0	0	0	0	0	0	0	0*4	0	0*4	0*4	0*4	0*4	0*4

Bit	Symbol	Bit Name	Description	R/W
b0	ITB4VE*4	TCIV4 Interrupt Skipping Link Enable	0: A/D converter start request signal TRG4BN and TCI4V interrupt skipping 1 are not linked 1: A/D converter start request signal TRG4BN and TCI4V interrupt skipping 1 are linked	R/W
b1	ITB3AE*4	TGIA3 Interrupt Skipping Link Enable	0: A/D converter start request signal TRG4BN and TGI3A interrupt skipping 1 are not linked 1: A/D converter start request signal TRG4BN and TGI3A interrupt skipping 1 are linked	R/W
b2	ITA4VE*4	TCIV4 Interrupt Skipping Link Enable	0: A/D converter start request signal TRG4AN and TCI4V interrupt skipping 1 are not linked 1: A/D converter start request signal TRG4AN and TCI4V interrupt skipping 1 are linked	R/W
b3	ITA3AE*4	TGIA3 Interrupt Skipping Link Enable	0: A/D converter start request signal TRG4AN and TGI3A interrupt skipping 1 are not linked 1: A/D converter start request signal TRG4AN and TGI3A interrupt skipping 1 are linked	R/W
b4	DT4BE*4	Down-Count TRG4BN Enable	0: A/D converter start requests (TRG4BN) disabled during MTU4.TCNT down-count operation 1: A/D converter start requests (TRG4BN) enabled during MTU4.TCNT down-count operation	R/W
b5	UT4BE	Up-Count TRG4BN Enable	0: A/D converter start requests (TRG4BN) disabled during MTU4.TCNT up-count operation 1: A/D converter start requests (TRG4BN) enabled during MTU4.TCNT up-count operation	R/W
b6	DT4AE*4	Down-Count TRG4AN Enable	0: A/D converter start requests (TRG4AN) disabled during MTU4.TCNT down-count operation 1: A/D converter start requests (TRG4AN) enabled during MTU4.TCNT down-count operation	R/W
b7	UT4AE	Up-Count TRG4AN Enable	0: A/D converter start requests (TRG4AN) disabled during MTU4.TCNT up-count operation 1: A/D converter up requests (TRG4AN) enabled during MTU4.TCNT down-count operation	R/W
b13 to b8	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W
b15, b14	BF[1:0]	MTU4.TADCOBRA/B Transfer Timing Select	See Table 16.49 for details. These bits specify the transfer timing from MTU4.TADCOBRA and MTU4.TADCOBRB to MTU4.TADCORA and MTU4.TADCORB.	R/W

Note 1. MTU4.TADCR must not be accessed in eight bits; it should always be accessed in 16 bits.
Note 2. When interrupt skipping is disabled (the T3AEN and T4VEN bits in TITCR1A are cleared to 0 or the T3ACOR and T4VCOR bits in TITCR1A are cleared to 0), do not link A/D converter start requests with interrupt skipping function 1 (clear the ITA3AE, ITA4VE, ITB3AE, and ITB4VE bits in MUT3_4.TADCR to 0).
Note 3. If link with interrupt skipping is enabled while interrupt skipping is disabled, A/D converter start requests will not be issued.
Note 4. Do not set to 1 in other than complementary PWM mode.

TADCR enables or disables A/D converter start requests and specifies whether to link A/D converter start requests with interrupt skipping function. The MTU3 has one TADCR each for MTU4 and MTU7.

Table 16.49 Setting of Transfer Timing by TADCR.BF[1:0] Bits (MTU4)

Bit 15	Bit 14	
BF1	**BF0**	**Description**
0	0	Does not transfer data from the cycle set buffer register (MTU4.TADCOBRA, MTU4.TADCOBRB) to the cycle set register (MTU4.TADCORA, MTU4.TADCORB).
0	1	Transfers data from the cycle set buffer register to the cycle set register at the crest of the MTU4.TCNT count.*1
1	0	Transfers data from the cycle set buffer register to the cycle set register at the trough of the MTU4.TCNT count.*2
1	1	Transfers data from the cycle set buffer register to the cycle set register at the crest and trough of the MTU4.TCNT count.*2

Note 1. Data is transferred from the cycle set buffer register (MTU4.TADCOBRA, MTU4.TADCOBRB) to the cycle set register (MTU4.TADCORA, MTU4.TADCORB) when the crest of the MTU4.TCNT count is reached or the MTU4.TGRD is written to in complementary PWM mode, when a compare match occurs between MTU3.TCNT and MTU3.TGRA in reset-synchronized PWM mode, or when a compare match occurs between MTU4.TCNT and MTU4.TGRA in PWM mode 1 or normal operation mode.

Note 2. These settings are prohibited when complementary PWM mode is not selected.

- TADCR (MTU7)

Address: 000C 1A40h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	BF[1:0]		—	—	—	—	—	—	UT7AE	DT7AE	UT7BE	DT7BE	ITA6AE	ITA7VE	ITB6AE	ITB7VE
Value after reset:	0	0	0	0	0	0	0	0	0	0*4	0	0*4	0*4	0*4	0*4	0*4

Bit	Symbol	Bit Name	Description	R/W
b0	ITB7VE*4	TCIV7 Interrupt Skipping Link Enable	0: A/D converter start request signal TRG7BN and TCI7V interrupt skipping 1 are not linked 1: A/D converter start request signal TRG7BN and TCI7V interrupt skipping 1 are linked	R/W
b1	ITB6AE*4	TGIA6 Interrupt Skipping Link Enable	0: A/D converter start request signal TRG7BN and TGI6A interrupt skipping 1 are not linked 1: A/D converter start request signal TRG7BN and TGI6A interrupt skipping 1 are linked	R/W
b2	ITA7VE*4	TCIV7 Interrupt Skipping Link Enable	0: A/D converter start request signal TRG7AN and TCI7V interrupt skipping 1 are not linked 1: A/D converter start request signal TRG7AN and TCI7V interrupt skipping 1 are linked	R/W
b3	ITA6AE*4	TGIA6 Interrupt Skipping Link Enable	0: A/D converter start request signal TRG7AN and TGI6A interrupt skipping 1 are not linked 1: A/D converter start request signal TRG7AN and TGI6A interrupt skipping 1 are linked	R/W
b4	DT7BE*4	Down-Count TRG7BN Enable	0: A/D converter start requests (TRG7BN) disabled during MTU7.TCNT down-count operation 1: A/D converter start requests (TRG7BN) enabled during MTU7.TCNT down-count operation	R/W
b5	DT7AE	Up-Count TRG7BN Enable	0: A/D converter start requests (TRG7BN) disabled during MTU7.TCNT up-count operation 1: A/D converter start requests (TRG7BN) enabled during MTU7.TCNT up-count operation	R/W
b6	DT7AE*4	Down-Count TRG7AN Enable	0: A/D converter start requests (TRG7AN) disabled during MTU7.TCNT down-count operation 1: A/D converter start requests (TRG7AN) enabled during MTU7.TCNT down-count operation	R/W
b7	UT7AE	Up-Count TRG7AN Enable	0: A/D converter start requests (TRG7AN) disabled during MTU7.TCNT up-count operation 1: A/D converter up requests (TRG7AN) enabled during MTU7.TCNT down-count operation	R/W
b13 to b8	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W
b15, b14	BF[1:0]	MTU7.TADCOBRA/B Transfer Timing Select	See Table 16.50 for details. These bits specify the transfer timing from MTU7.TADCOBRA and MTU7.TADCOBRB to MTU7.TADCORA and MTU7.TADCORB.	R/W

Note 1. MTU7.TADCR must not be accessed in eight bits; it should always be accessed in 16 bits.
Note 2. When interrupt skipping is disabled (the T6AEN and T7VEN bits in TITCR1B are cleared to 0 or the T6ACOR and T7VCOR bits in TITCR1B are cleared to 0), do not link A/D converter start requests with interrupt skipping function 1 (clear the ITA6AE, ITA7VE, ITB6AE, and ITB7VE bits in MUT3_7.TADCR to 0).
Note 3. If link with interrupt skipping is enabled while interrupt skipping is disabled, A/D converter start requests will not be issued.
Note 4. Do not set to 1 in other than complementary PWM mode.

Table 16.50 Setting of Transfer Timing by TADCR.BF[1:0] Bits (MTU7)

Bit 15	Bit 14	
BF1	**BF0**	**Description**
0	0	Does not transfer data from the cycle set buffer register (MTU7.TADCOBRA, MTU7.TADCOBRB) to the cycle set register (MTU7.TADCORA, MTU7.TADCORB).
0	1	Transfers data from the cycle set buffer register to the cycle set register at the crest of the MTU7.TCNT count.*1
1	0	Transfers data from the cycle set buffer register to the cycle set register at the trough of the MTU7.TCNT count.*2
1	1	Transfers data from the cycle set buffer register to the cycle set register at the crest and trough of the MTU7.TCNT count.*2

Note 1. Data is transferred from the cycle set buffer register (MTU7.TADCOBRA, MTU7.TADCOBRB) to the cycle set register (MTU7.TADCORA, MTU7.TADCORB) when the crest of the MTU7.TCNT count is reached or the MTU7.TGRD is written to in complementary PWM mode, when a compare match occurs between MTU6.TCNT and MTU6.TGRA in reset-synchronized PWM mode, or when a compare match occurs between MTU7.TCNT and MTU7.TGRA in PWM mode 1 or normal operation mode.

Note 2. These settings are prohibited when complementary PWM mode is not selected.

16.2.30 Timer A/D Converter Start Request Cycle Set Registers (TADCORA and TADCORB)

Address: MTU4.TADCORA 000C 1244h, MTU4.TADCORB 000C 1246h
MTU7.TADCORA 000C 1A44h, MTU7.TADCORB 000C 1A46h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Note 1. MTUn.TADCORA and MTUn.TADCORB (n = 4 or 7) must not be accessed in eight bits; they should always be accessed in 16 bits.

Note 2. When the A/D converter start request delaying function linked with skipping function 1 (for details, see section 16.3.9 (4), A/D Converter Start Request Delaying Function Linked with Interrupt Skipping Function 1) is used, the value of this register should be 0002h to TCDRA setting - 2 in MTU4 and 0002h to TCDRB setting - 2 in MTU7.

Note 3. When interrupt skipping function 2 is used and the difference between the MTUn.TADCORA value and the MTUn.TADCORB value is small, the skipping count may not be counted correctly and the A/D converter start request may not be generated with the expected timing in some cases. The TADCORA and TADCORB values should satisfy the following conditions.

(1) When skipping function 2 is specified with the skipping count set to 0
- The difference between the MTUn.TADCORA and MTUn.TADCORB values should be equal to or greater than 4.
- The MTUn.TADCORA compare interval should be equal to or greater than 4 ICLK cycles (the MTUn.TADCORA update value should be the previous value + 4 or greater, or previous value - 4 or smaller).
- The MTUn.TADCORB compare interval should be equal to or greater than 4 ICLK cycles (the MTUn.TADCORB update value should be the previous value + 4 or greater, or previous value - 4 or smaller).

(2) When skipping function 2 is specified with the skipping count set to 1 or greater
- The difference between the MTUn.TADCORA and MTUn.TADCORB values should be equal to or greater than 2.
- The MTUn.TADCORB compare interval should be equal to or greater than 2 ICLK cycles (the MTUn.TADCOR update value should be the previous value + 2 or greater, or previous value - 2 or smaller)

TADCORA and TADCORB are 16-bit readable/writable registers that issue a corresponding A/D converter start request when the MTUn.TCNT (n = 4 or 7) count reaches the value in TADCORA or TADCORB.
MTUn.TADCORA and TADCORB are initialized to FFFFh by a reset.

16.2.31 Timer A/D Converter Start Request Cycle Set Buffer Registers (TADCOBRA and TADCOBRB)

Address: MTU4.TADCORA 000C 1248h, MTU4.TADCORB 000C 124Ah
MTU7.TADCORA 000C 1A48h, MTU7.TADCORB 000C 1A4Ah

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Note 1. TADCOBRA and TADCOBRB must not be accessed in eight bits; it should always be accessed in 16 bits.

TADCOBRA and TADCOBRB are 16-bit readable/writable registers whose values are transferred to TADCORA and TADCORB, respectively, when the crest or trough of the MTUn.TCNT count is reached.
TADCOBRA and TADCOBRB are initialized to FFFFh by a reset.

16.2.32 Timer Interrupt Skipping Mode Registers (TITMRA and TITMRB)

Address: TITMRA 000C 123Ah, TITMRB 000C 1A3Ah

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	TITM
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	TITM	Interrupt Skipping Function Select	Selects one of the two types of interrupt skipping functions shown in Table 16.51.	R/W
b7 to b1	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W

TITMRA and TITMRB are used to select either of two skipping functions for the TITMRA and TITMRB registers.

Table 16.51 Interrupt Skipping Function Selected through TITM Bit

Bit 0	
TITM	**Description**
0	Selects interrupt skipping function 1 *1
1	Selects interrupt skipping function 2 *2

Note 1. TITCR1A or TITCR1B enables interrupt skipping function 1.
Note 2. TITCR2A or TITCR2B enables interrupt skipping function 2.

16.2.33 Timer Interrupt Skipping Set Registers 1 (TITCR1A and TITCR1B)

- TITCR1A

Address: TITMRA 000C 123Ah, TITMRB 000C 1A3Ah

	b7	b6	b5	b4	b3	b2	b1	b0
	T3AEN		T3ACOR[2:0]			T4VEN	T4VCOR[2:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b2 to b0	T4VCOR[2:0]	TCIV4 Interrupt Skipping Count Setting	These bits specify the TCIV4 interrupt skipping count within the range from 0 to 7. *1 For details, see Table 16.52.	R/W
b3	T4VEN	T4VEN	0: TCIV4 interrupt skipping disabled 1: TCIV4 interrupt skipping enabled	R/W
b6 to b4	T3ACOR[2:0]	TGIA3 Interrupt Skipping Count Setting	These bits specify the TGIA3 interrupt skipping count within the range from 0 to 7. *1 For details, see Table 16.53.	R/W
b7	T3AEN	T3AEN	0: TGIA3 interrupt skipping disabled 1: TGIA3 interrupt skipping enabled	R/W

Note 1. When 0 is specified for the interrupt skipping count, no interrupt skipping will be performed.
Before changing the interrupt skipping count, be sure to clear the TITCR1A.T3AEN and TITCR1A.T4VEN bits to 0 to clear the skipping counter (TITCNT1A).

TITCR1A and TITCR1B enable or disable interrupt skipping and specify the interrupt skipping count. This setting is valid only while TITMRA or TITMRB is set to 0; when TITMRA or TITMRB is set to 1, the setting in the corresponding TITCR1 register is cleared.

- TITCR1B

Address: 000C 1230h

	b7	b6	b5	b4	b3	b2	b1	b0
	T6AEN	T6ACOR[2:0]			T7VEN	T7VCOR[2:0]		
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b2 to b0	T7VCOR[2:0]	TCIV7 Interrupt Skipping Count Setting	These bits specify the TCIV7 interrupt skipping count within the range from 0 to 7. *1 For details, see Table 16.54.	R/W
b3	T7VEN	T7VEN	0: TCIV7 interrupt skipping disabled 1: TCIV7 interrupt skipping enabled	R/W
b6 to b4	T6ACOR[2:0]	TGIA6 Interrupt Skipping Count Setting	These bits specify the TGIA6 interrupt skipping count within the range from 0 to 7. *1 For details, see Table 16.55.	R/W
b7	T6AEN	T6AEN	0: TGIA6 interrupt skipping disabled 1: TGIA6 interrupt skipping enabled	R/W

Note 1. When 0 is specified for the interrupt skipping count, no interrupt skipping will be performed.
Before changing the interrupt skipping count, be sure to clear the TITCR1B.T6AEN and TITCR1B.T7VEN bits to 0 to clear the skipping counter (TITCNT1B).

Table 16.52 Setting of Interrupt Skipping Count by T4VCOR[2:0] Bits

Bit 2	Bit 1	Bit 0	Description
T4VCOR2	T4VCOR1	T4VCOR0	
0	0	0	Does not skip TCIV4 interrupts.
0	0	1	Sets the TCIV4 interrupt skipping count to 1.
0	1	0	Sets the TCIV4 interrupt skipping count to 2.
0	1	1	Sets the TCIV4 interrupt skipping count to 3.
1	0	0	Sets the TCIV4 interrupt skipping count to 4.
1	0	1	Sets the TCIV4 interrupt skipping count to 5.
1	1	0	Sets the TCIV4 interrupt skipping count to 6.
1	1	1	Sets the TCIV4 interrupt skipping count to 7.

Table 16.53 Setting of Interrupt Skipping Count by T3ACOR[2:0] Bits

Bit 6	Bit 5	Bit 4	
T3ACOR2	T3ACOR1	T3ACOR0	Description
0	0	0	Does not skip TGIA3 interrupts.
0	0	1	Sets the TGIA3 interrupt skipping count to 1.
0	1	0	Sets the TGIA3 interrupt skipping count to 2.
0	1	1	Sets the TGIA3 interrupt skipping count to 3.
1	0	0	Sets the TGIA3 interrupt skipping count to 4.
1	0	1	Sets the TGIA3 interrupt skipping count to 5.
1	1	0	Sets the TGIA3 interrupt skipping count to 6.
1	1	1	Sets the TGIA3 interrupt skipping count to 7.

Table 16.54 Setting of Interrupt Skipping Count by T7VCOR[2:0] Bits

Bit 2	Bit 1	Bit 0	
T7VCOR2	T7VCOR1	T7VCOR0	Description
0	0	0	Does not skip TCIV7 interrupts.
0	0	1	Sets the TCIV7 interrupt skipping count to 1.
0	1	0	Sets the TCIV7 interrupt skipping count to 2.
0	1	1	Sets the TCIV7 interrupt skipping count to 3.
1	0	0	Sets the TCIV7 interrupt skipping count to 4.
1	0	1	Sets the TCIV7 interrupt skipping count to 5.
1	1	0	Sets the TCIV7 interrupt skipping count to 6.
1	1	1	Sets the TCIV7 interrupt skipping count to 7.

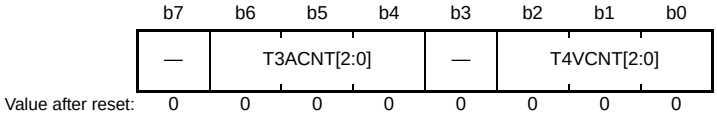
Table 16.55 Setting of Interrupt Skipping Count by T6ACOR[2:0] Bits

Bit 6	Bit 5	Bit 4	
T6ACOR2	**T6ACOR1**	**T6ACOR0**	**Description**
0	0	0	Does not skip TGIA6 interrupts.
0	0	1	Sets the TGIA6 interrupt skipping count to 1.
0	1	0	Sets the TGIA6 interrupt skipping count to 2.
0	1	1	Sets the TGIA6 interrupt skipping count to 3.
1	0	0	Sets the TGIA6 interrupt skipping count to 4.
1	0	1	Sets the TGIA6 interrupt skipping count to 5.
1	1	0	Sets the TGIA6 interrupt skipping count to 6.
1	1	1	Sets the TGIA6 interrupt skipping count to 7.

16.2.34 Timer Interrupt Skipping Counters 1 (TITCNT1A and TITCNT1B)

- TITCNT1A

Address: 000C 1231h



Bit	Symbol	Bit Name	Description	R/W
b2 to b0	T4VCNT[2:0]	TCIV4 Interrupt Counter	While the T4VEN bit in TITCR1A is set to 1, the count in these bits is incremented every time a TCIV4 interrupt occurs.	R
b3	—	Reserved	This bit is always read as 0. Writing to this bit has no effect.	R
b6 to b4	T3ACNT[2:0]	TGIA3 Interrupt Counter	While the T3AEN bit in TITCR1A is set to 1, the count in these bits is incremented every time a TGIA3 interrupt occurs.	R
b7	—	Reserved	This bit is always read as 0. Writing to this bit has no effect.	R

Note 1. To clear the TITCNT1A, clear the T3AEN and T4VEN bits in TITCR1A to 0.

TITCNT1A and TITCNT1B are 8-bit readable/writable counters. TITCNTA and TITCNTB retain their values even after stopping the count operation of MTU3.TCNT and MTU4.TCNT (MTU6.TCNT and MTU7.TCNT).

T4VCNT[2:0] Bits (TCIV4 Interrupt Counter)

While the T4VEN bit in TITCR1A is set to 1, the count in these bits is incremented every time a TCIV4 interrupt occurs.
[Clearing conditions]

- When the TITM bit in TITMRA is 1
- When the T4VEN bit in TITCR1A is cleared to 0
- When the T4VCOR[2:0] bits in TITCR1A are cleared to 000b
- When the T4VCNT[2:0] bits in TITCNT1A match the T4VCOR[2:0] bits in TITCR1A

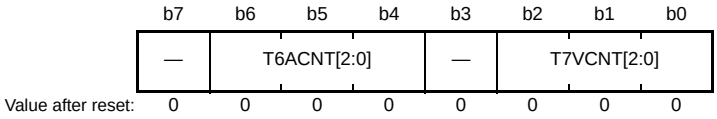
T3ACNT[2:0] Bits (TGIA3 Interrupt Counter)

While the T3AEN bit in TITCR1A is set to 1, the count in these bits is incremented every time a TGIA3 interrupt occurs.
[Clearing conditions]

- When the TITM bit in TITMRA is 1
- When the T3AEN bit in TITCR1A is cleared to 0
- When the T3ACOR[2:0] bits in TITCR1A are cleared to 000b
- When the T3ACNT[2:0] bits in TITCNT1A match the T3ACOR[2:0] bits in TITCR1A

- TITCNT1B

Address: 000C 1A31h



Bit	Symbol	Bit Name	Description	R/W
b2 to b0	T7VCNT[2:0]	TCIV7 Interrupt Counter	While the T7VEN bit in TITCR1B is set to 1, the count in these bits is incremented every time a TCIV7 interrupt occurs.	R
b3	—	Reserved	This bit is always read as 0. Writing to this bit has no effect.	R
b6 to b4	T6ACNT[2:0]	TGIA6 Interrupt Counter	While the T6AEN bit in TITCR1B is set to 1, the count in these bits is incremented every time a TGIA6 interrupt occurs.	R
b7	—	Reserved	This bit is always read as 0. Writing to this bit has no effect.	R

Note 1. To clear the TITCNT1B, clear the T6AEN and T7VEN bits in TITCR1B to 0.

T7VCNT[2:0] Bits (TCIV7 Interrupt Counter)

While the T7VEN bit in TITCR1B is set to 1, the count in these bits is incremented every time a TCIV7 interrupt occurs.
[Clearing conditions]

- When the TITM bit in TITMRB is 1
- When the T7VEN bit in TITCR1B is cleared to 0
- When the T7VCOR[2:0] bits in TITCR1B are cleared to 000b
- When the T7VCNT[2:0] bits in TITCNT1B match the T7VCOR[2:0] bits in TITCR1B

T6ACNT[2:0] Bits (TGIA6 Interrupt Counter)

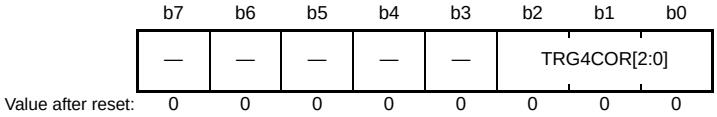
While the T6AEN bit in TITCR1B is set to 1, the count in these bits is incremented every time a TGIA6 interrupt occurs.
[Clearing conditions]

- When the TITM bit in TITMRB is 1
- When the T6AEN bit in TITCR1B is cleared to 0
- When the T6ACOR[2:0] bits in TITCR1B are cleared to 000b
- When the T6ACNT[2:0] bits in TITCNT1B match the T6ACOR[2:0] bits in TITCR1B

16.2.35 Timer Interrupt Skipping Set Registers 2 (TITCR2A and TITCR2B)

- TITCR2A

Address: 000C 123Bh



Bit	Symbol	Bit Name	Description	R/W
b2 to b0	TRG4COR[2:0]	TRG4AN/TRG4BN Interrupt Skipping Count Setting	These bits specify the TRG4AN/TRG4BN interrupt skipping count within the range from 0 to 7. For details, see Table 16.56.	R/W
b7 to b3	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W

TITCR2A and TITCR2B specify the interrupt skipping count for TRG4AN and TRG4BN (TRG7AN and TRG7BN). This setting is valid only while TITMRA or TITMRB is set to 1.

Table 16.56 Setting of Interrupt Skipping Count by TRG4COR[2:0] Bits

Bit 2	Bit 1	Bit 0	
TRG4COR2	TRG4COR1	TRG4COR0	Description
0	0	0	Does not skip TRG4AN and TRG4BN interrupts.
0	0	1	Sets the TRG4AN and TRG4BN interrupt skipping count to 1.
0	1	0	Sets the TRG4AN and TRG4BN interrupt skipping count to 2.
0	1	1	Sets the TRG4AN and TRG4BN interrupt skipping count to 3.
1	0	0	Sets the TRG4AN and TRG4BN interrupt skipping count to 4.
1	0	1	Sets the TRG4AN and TRG4BN interrupt skipping count to 5.
1	1	0	Sets the TRG4AN and TRG4BN interrupt skipping count to 6.
1	1	1	Sets the TRG4AN and TRG4BN interrupt skipping count to 7.

- TITCR2B

Address: 000C 1A3Bh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	TRG7COR[2:0]		
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b2 to b0	TRG7COR[2:0]	TRG7AN/TRG7BN Interrupt Skipping Count Setting	These bits specify the TRG7AN/TRG7BN interrupt skipping count within the range from 0 to 7. For details, see Table 16.57.	R/W
b7 to b3	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W

Table 16.57 Setting of Interrupt Skipping Count by TRG7COR[2:0] Bits

Bit 2	Bit 1	Bit 0	
TRG7COR2	TRG7COR1	TRG7COR0	Description
0	0	0	Does not skip TRG7AN and TRG7BN interrupts.
0	0	1	Sets the TRG7AN and TRG7BN interrupt skipping count to 1.
0	1	0	Sets the TRG7AN and TRG7BN interrupt skipping count to 2.
0	1	1	Sets the TRG7AN and TRG7BN interrupt skipping count to 3.
1	0	0	Sets the TRG7AN and TRG7BN interrupt skipping count to 4.
1	0	1	Sets the TRG7AN and TRG7BN interrupt skipping count to 5.
1	1	0	Sets the TRG7AN and TRG7BN interrupt skipping count to 6.
1	1	1	Sets the TRG7AN and TRG7BN interrupt skipping count to 7.

16.2.36 Timer Interrupt Skipping Counters 2 (TITCNT2A and TITCNT2B)

- TITCNT2A

Address: 000C 123Ch

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	TRG4CNT[2:0]		
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b2 to b0	TRG4CNT[2:0]	TRG4AN/TRG4BN Interrupt Counter	These bits start counting from the value set in TRG4COR[2:0] and the count decrements every time TRG4AN or TRG4BN is generated. When the count reaches 0 and is reloaded, the TRG4AN and TRG4BN interrupts become valid.	R
b7 to b3	—	Reserved	These bits are always read as 0. Writing to this bit has no effect.	R

TITCNT2A and TITCNT2B start counting from the values set in the TRG4COR[2:0] and TRG7COR[2:0] bits and the count decrements every time TRG4AN or TRG4BN (TITCNT2A) is generated or TRG7AN or TRG7BN (TITCNT2B) is generated. When the count reaches 0 and is reloaded, the TRG4AN and TRG4BN interrupts or the TRG7AN and TRG7BN interrupts become valid.

TRG4CNT[2:0] Bits (TRG4AN/TRG4BN Interrupt Counter)

These bits start counting from the value set in the TRG4COR[2:0] bits and the count decrements every time a TRG4AN or TRG4BN interrupt is generated. When the count reaches 0 and is reloaded, the TRG4AN and TRG4BN interrupts become valid.

[Clearing conditions]

- When the TITM bit in TITMRA is 1
- When the TRG4COR[2:0] bits in TITCR2A are cleared to 000b
- When the count of TRG4AN and TRG4BN occurrence matches the TRG4COR[2:0] value in TITCR2A

- TITCNT2B

Address: 000C 1A3Ch

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	TRG7CNT[2:0]		
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b2 to b0	TRG7CNT[2:0]	TRG7AN/TRG7BN Interrupt Counter	These bits start counting from the value set in TRG7COR[2:0] and the count decrements every time TRG7AN or TRG7BN is generated. When the count reaches 0 and is reloaded, the TRG7AN and TRG7BN interrupts become valid.	R
b7 to b3	—	Reserved	These bits are always read as 0. Writing to this bit has no effect.	R

TRG7CNT[2:0] Bits (TRG7AN/TRG7BN Interrupt Counter)

These bits start counting from the value set in the TRG7COR[2:0] bits and the count decrements every time a TRG7AN or TRG7BN interrupt is generated. When the count reaches 0 and is reloaded, the TRG7AN and TRG7BN interrupts become valid.

[Clearing conditions]

- When the TITM bit in TITMRB is 1
- When the TRG7COR[2:0] bits in TITCR2B are cleared to 000b
- When the count of TRG7AN and TRG7BN occurrence matches the TRG7COR[2:0] value in TITCR2B

16.2.37 Bus Master Interface

The timer counters (TCNT), general registers (TGR), timer subcounters (TCNTSA and TCNTSB), timer cycle buffer registers (TCBRA and TCBRB), timer dead time data registers (TDDRA and TDDRB), timer cycle data registers (TCDRA and TCDRB), timer A/D converter start request control registers (MTU4.TADCR and MTU7.TADCR), timer A/D converter start request cycle set registers (MTU4.TADCORA, MTU4.TADCORB, MTU7.TADCORA, and MTU7.TADCORB), and timer A/D converter start request cycle set buffer registers (MTU4.TADCOBRA, MTU4.TADCOBRB, MTU7.TADCOBRA, and MTU7.TADCOBRB) are 16-bit registers. A 16-bit data bus to the bus master enables 16-bit read/write access. 8-bit read/write is not allowed. Always access the registers in 16-bit units.
All registers other than the above registers are 8-bit registers. A 16-bit data bus to the CPU enables 16-bit read/write access. These registers can also be accessed in 8-bit units.

16.3 Operation

16.3.1 Basic Functions

Each channel has TCNT and TGR. TCNT performs up-counting, and is also capable of free-running operation, periodic counting, and external event counting.
Each TGR can be used as an input capture register or an output compare register.

(1) Counter Operation

When one of bits CST0 to CST4 in TSTRA, bits CST6 and CST7 in TSTRB, and bits CSTU5, CSTV5, and CSTW5 in MTU5.TSTR is set to 1, TCNT for the corresponding channel begins counting. TCNT can operate as a free-running counter, periodic counter, for example.

(a) Example of Count Operation Setting Procedure

Figure 16.5 shows an example of the count operation setting procedure.

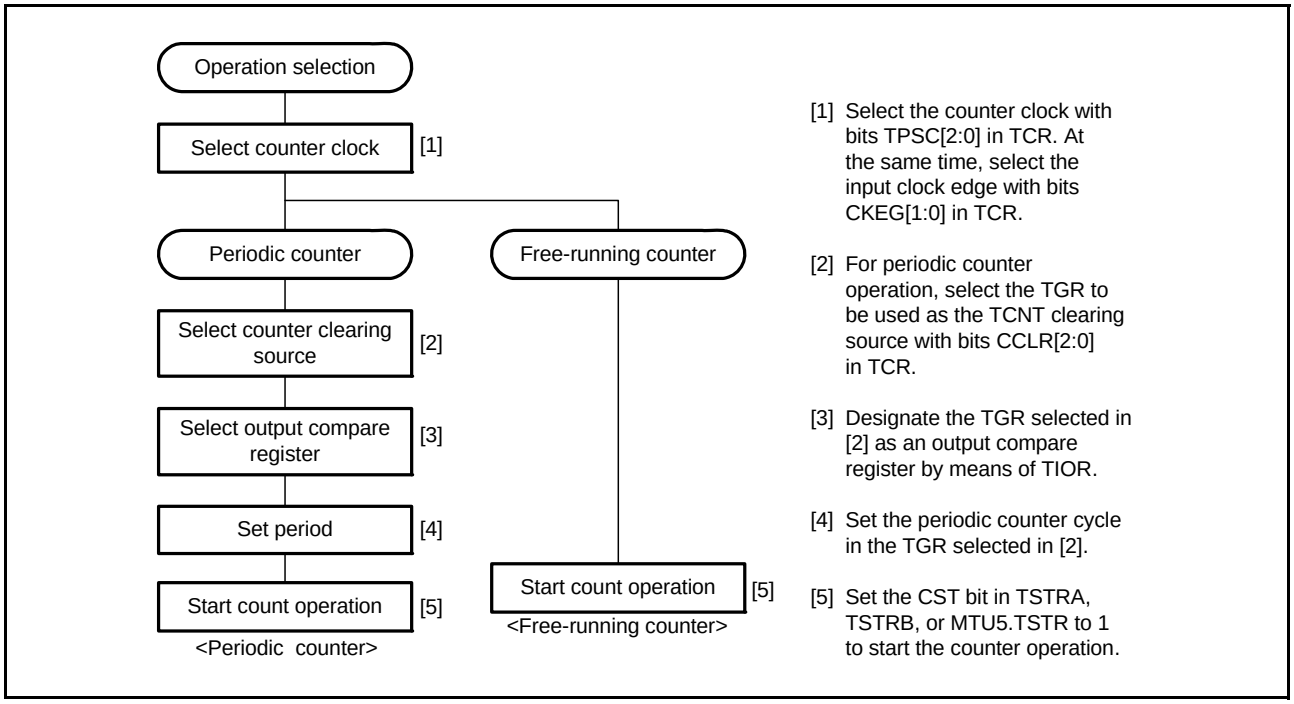


Figure 16.5 Example of Counter Operation Setting Procedure

(b) Free-Running Count Operation and Periodic Count Operation

Immediately after a reset, the MTU's TCNT counters are all designated as free-running counters. When the relevant bit in TSTRA, TSTRB, or MTU5.TSTR is set to 1, the corresponding TCNT counter starts up-count operation as a free-running counter. When TCNT overflows (from FFFFh to 0000h), the TSR.TCFV flag is set to 1. If the corresponding TIER.TCIEV bit is 1 at this point, the MTU requests an interrupt. After an overflow, TCNT starts counting up again from 0000h.

Figure 16.6 illustrates free-running counter operation.

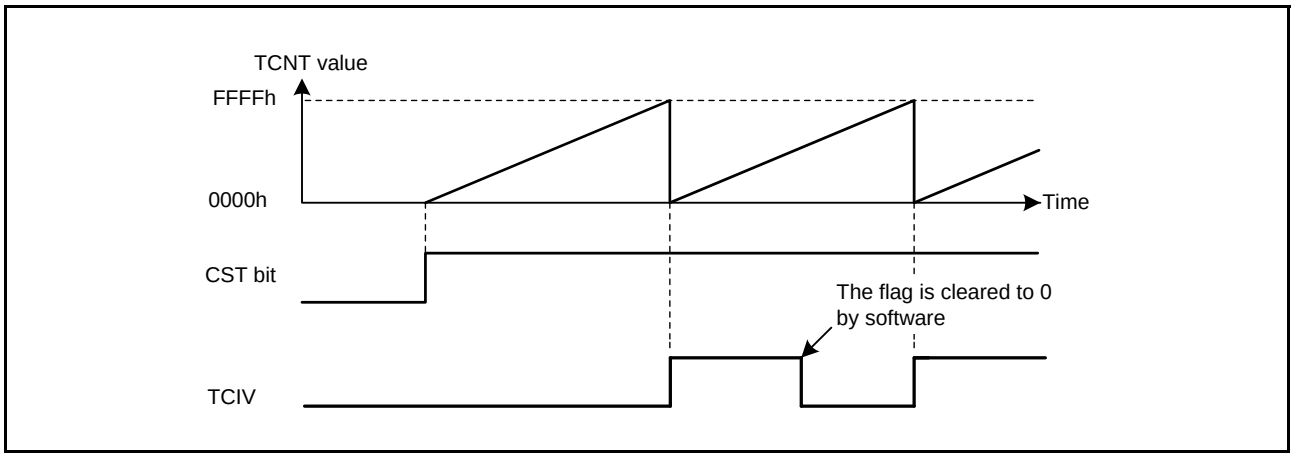


Figure 16.6 Free-Running Counter Operation

When compare match is selected as the TCNT clearing source, TCNT for the relevant channel performs periodic count operation. TGR for setting the cycle is designated as an output compare register, and counter clearing by compare match is selected by means of bits CCLR[2:0] in TCR. After the settings have been made, TCNT starts up-count operation as a periodic counter when the corresponding bit in TSTRA, TSTRB or MTU5.TSTR is set to 1. When the count matches the value in TGR, the TSR.TGF flag is set to 1 and TCNT is cleared to 0000h.

If the value of the corresponding TIER.TGIE bit is 1 at this point, the MTU requests an interrupt. After a compare match, TCNT starts counting up again from 0000h.

Figure 16.7 illustrates periodic counter operation.

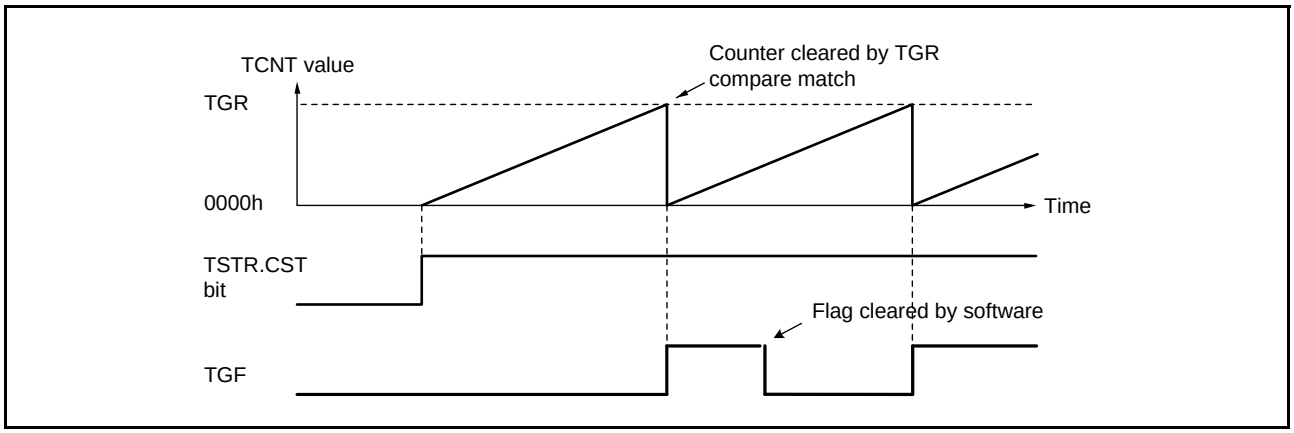


Figure 16.7 Periodic Counter Operation

(2) Waveform Output by Compare Match

The MTU can output low or high or toggles output from the corresponding output pin using compare match.

(a) Example of Procedure for Setting Waveform Output by Compare Match

Figure 16.8 shows an example of the procedure for setting waveform output by compare match

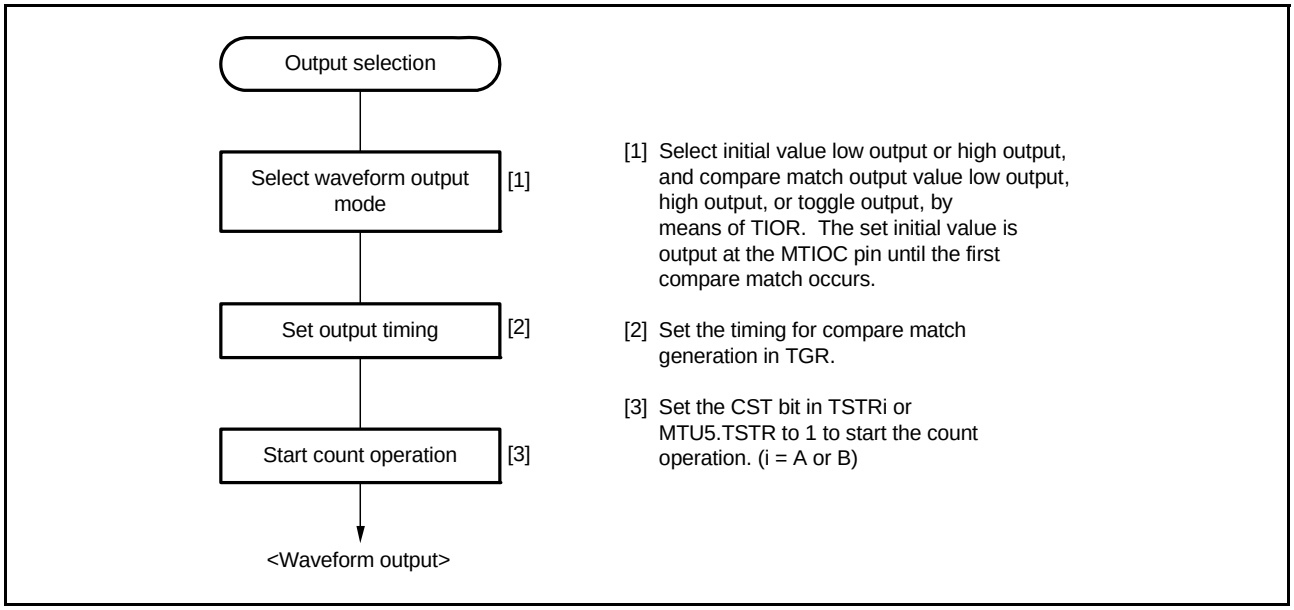


Figure 16.8 Example of Procedure for Setting Waveform Output by Compare Match

(b) Examples of Waveform Output Operation

Figure 16.9 shows an example of low output and high output.
In this example, TCNT has been designated as a free-running counter, and settings have been made so that high is output by compare match A and low is output by compare match B. When the pin level is the same as the specified level, the pin level does not change.

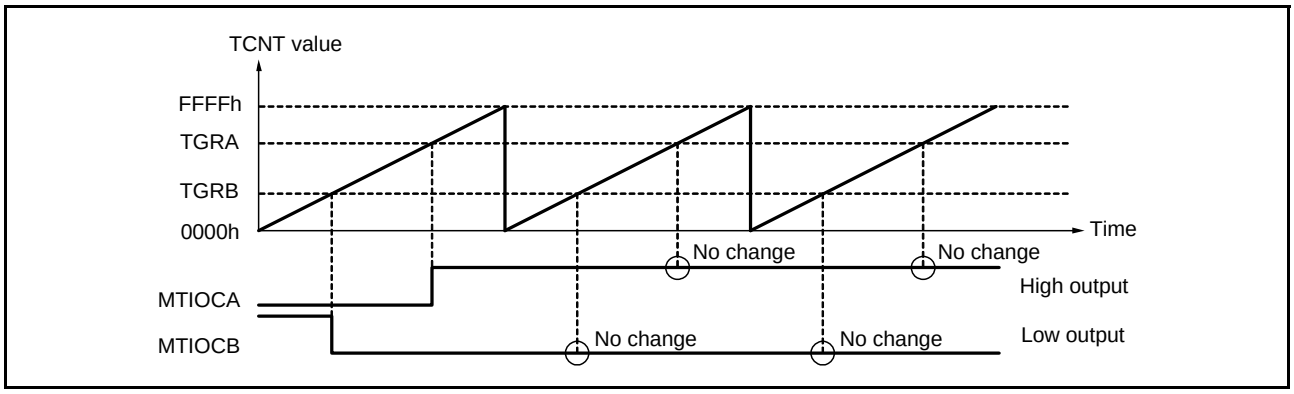


Figure 16.9 Example of low output and high output Operation

Figure 16.10 shows an example of toggle output.
In this example, TCNT has been designated as a periodic counter (with counter clearing on compare match B), and settings have been made so that the output is toggled by both compare match A and compare match B.

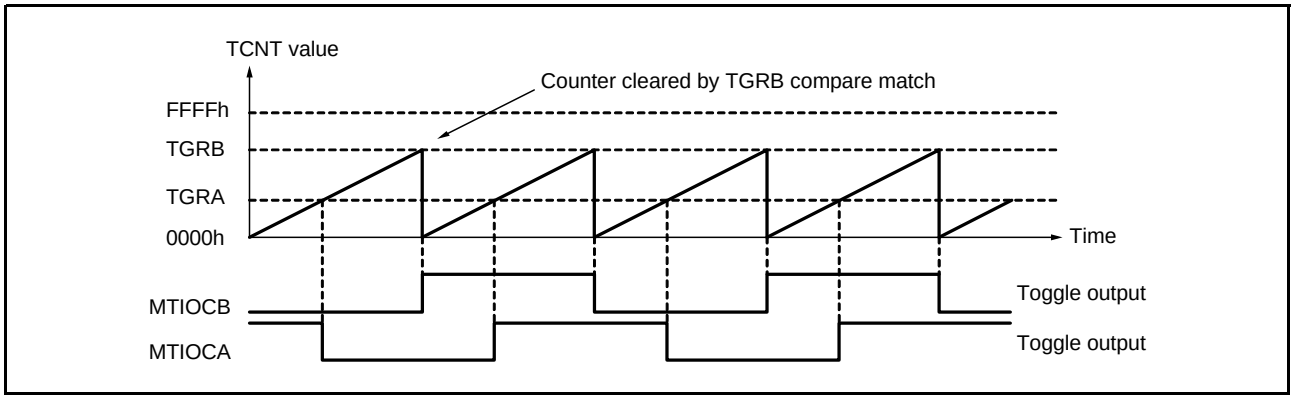


Figure 16.10 Example of Toggle Output Operation

(3) Input Capture Function

The TCNT value can be transferred to TGR on detection of the MTIOC pin input edge.
The rising edge, falling edge, or both edges can be selected as the detection edge. For MTU0 and MTU1, another channel's counter input clock or compare match signal can also be specified as the input capture source.
Note:When another channel's counter input clock is used as the input capture input for MTU0 and MTU1, ICLK/1 should not be selected as the counter input clock used for input capture input. Input capture will not be generated if ICLK/1 is selected.

(a) Example of Input Capture Operation Setting Procedure

Figure 16.11 shows an example of the input capture operation setting procedure.

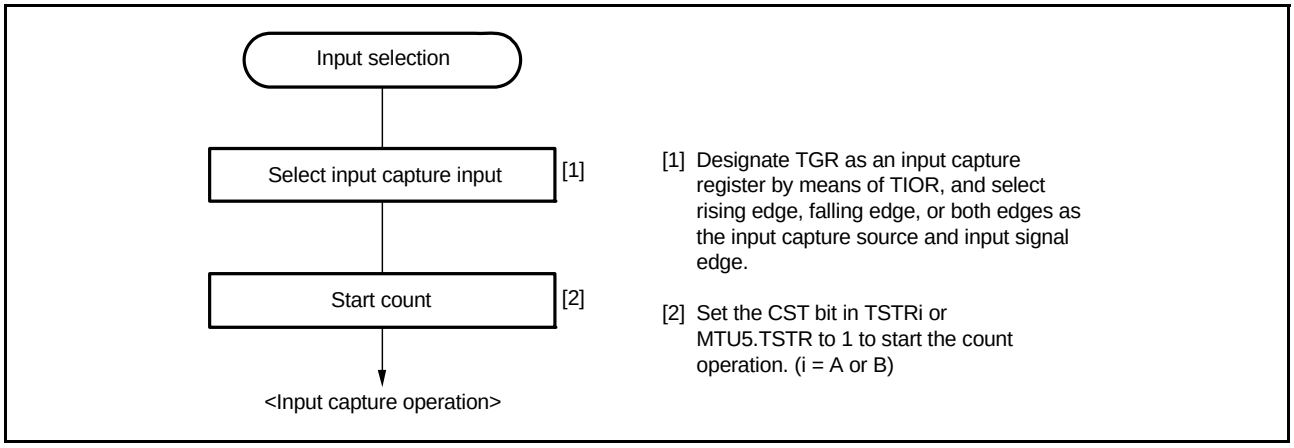


Figure 16.11 Example of Input Capture Operation Setting Procedure

(b) Example of Input Capture Operation

Figure 16.12 shows an example of input capture operation.
In this example, both rising and falling edges have been selected as the MTIOCA pin input capture input edge, the falling edge has been selected as the MTIOCB pin input capture input edge, and counter clearing by TGRB input capture has been designated for TCNT.

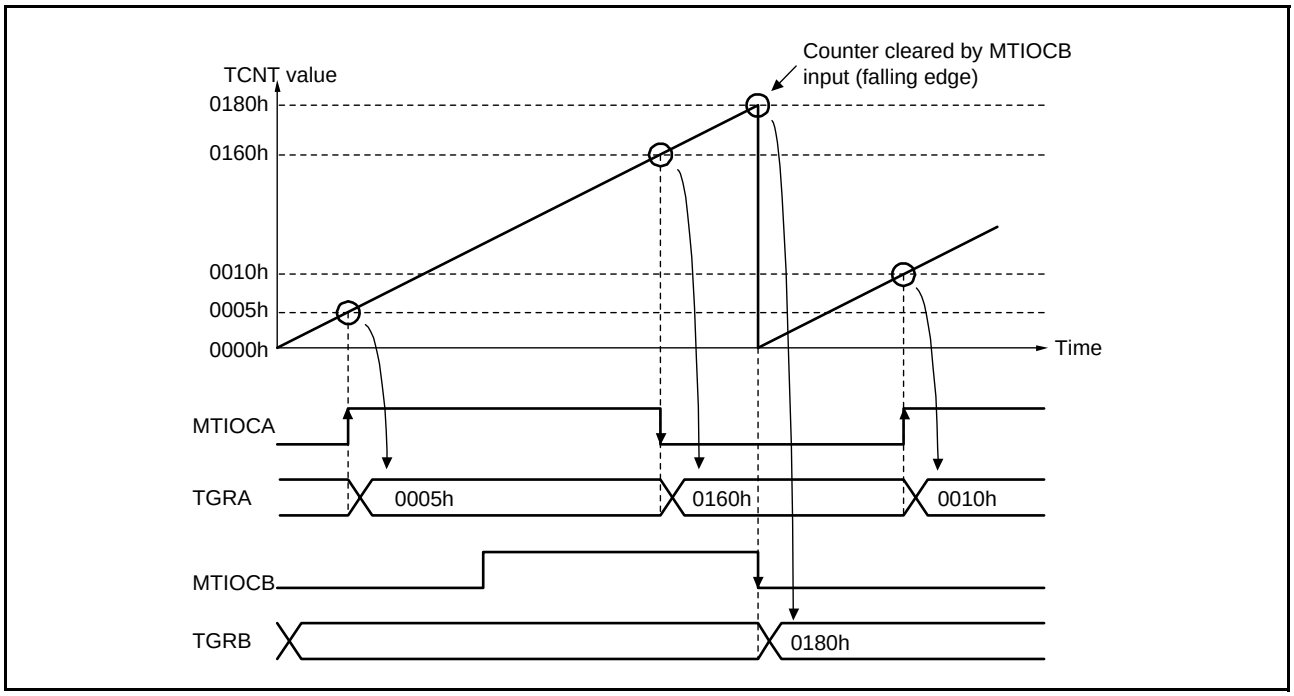


Figure 16.12 Example of Input Capture Operation

16.3.2 Synchronous Operation

In synchronous operation, the values in multiple TCNT counters can be modified simultaneously (synchronous presetting). In addition, multiple TCNT counters can be cleared simultaneously (synchronous clearing) by making the appropriate setting in TCR.
Synchronous operation increases the number of TGR registers assigned to a single time base.
MTU0 to MTU4, MTU6, and MTU7 can all be designated for synchronous operation. MTU5 cannot be used for synchronous operation.

(1) Example of Synchronous Operation Setting Procedure

Figure 16.13 shows an example of the synchronous operation setting procedure.

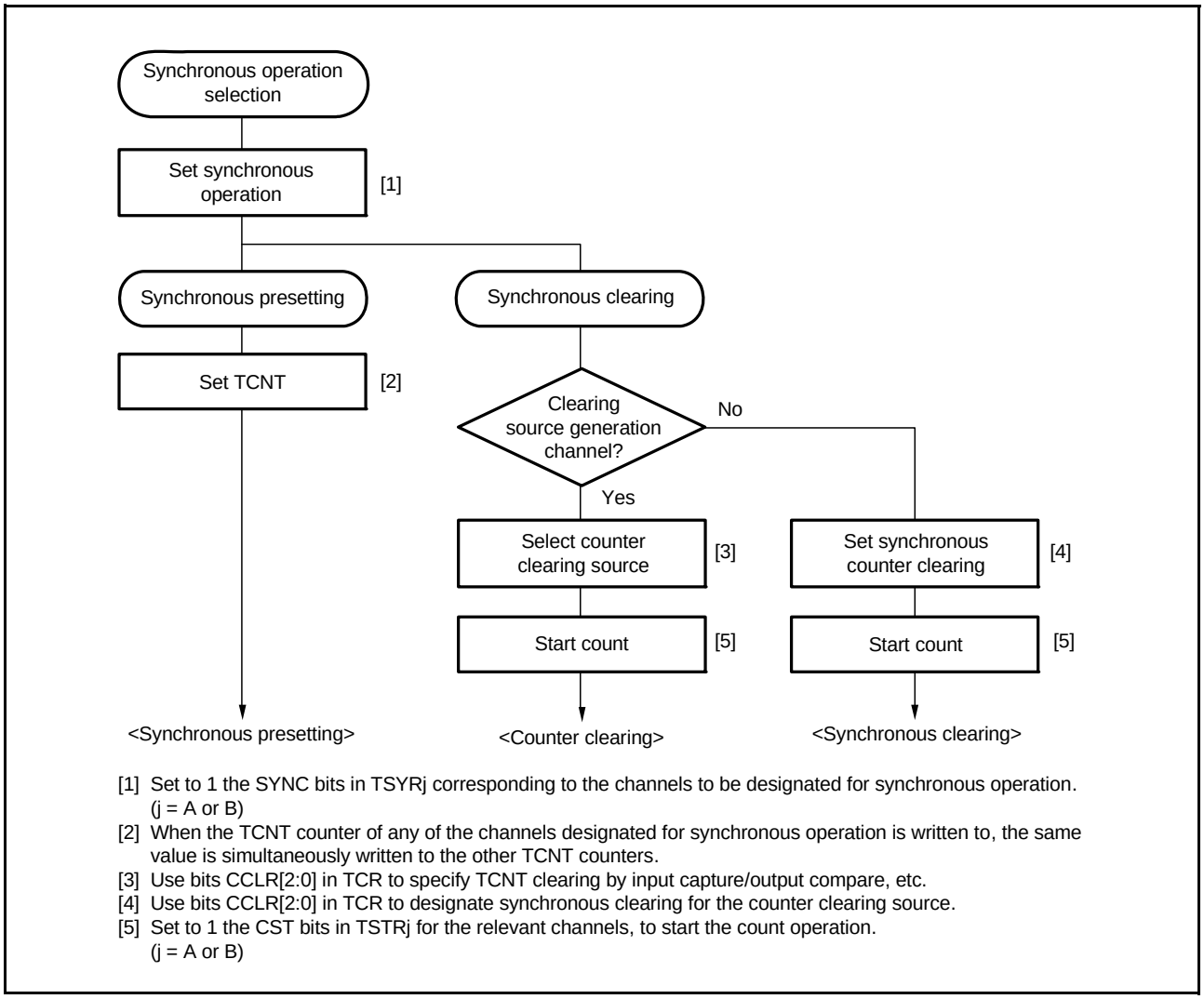


Figure 16.13 Example of Synchronous Operation Setting Procedure

(2) Example of Synchronous Operation

Figure 16.14 shows an example of synchronous operation.
In this example, synchronous operation and PWM mode 1 have been designated for MTU0 to MTU2, MTU0.TGRB compare match has been set as the counter clearing source in MTU0, and synchronous clearing has been set for the counter clearing source in MTU1 and MTU2.
Three-phase PWM waveforms are output from pins MTIOC0A, MTIOC1A, and MTIOC2A. At this time, synchronous presetting and synchronous clearing by MTU0.TGRB compare match are performed for the TCNT counters in cMTU1 and MTU2, and the data set in MTU0.TGRB is used as the PWM cycle.
For details of PWM modes, see section 16.3.5, PWM Modes .

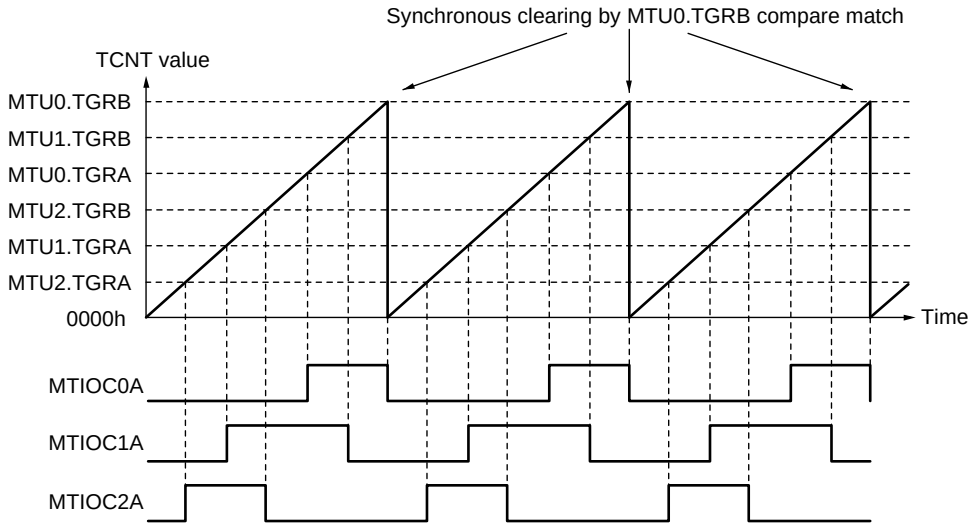


Figure 16.14 Example of Synchronous Operation

16.3.3 Buffer Operation

Buffer operation, provided for MTU0, MTU3, MTU4, MTU6, and MTU7, enables TGRC and TGRD to be used as buffer registers. In MTU0, TGRF can also be used as a buffer register.
Buffer operation differs depending on whether TGR has been designated as an input capture register or as a compare match register.

Note: • MTU0.TGRE cannot be designated as an input capture register and can only operate as a compare match register.

shows the register combinations used in buffer operation.

Table 16.58 Register Combinations in Buffer Operation

Channel	Timer General Register	Buffer Register
MTU0	TGRA	TGRC
	TGRB	TGRD
	TGRE	TGRF
MTU3	TGRA	TGRC
	TGRB	TGRD
MTU4	TGRA	TGRC
	TGRB	TGRD
MTU6	TGRA	TGRC
	TGRB	TGRD
MTU7	TGRA	TGRC
	TGRB	TGRD

- When TGR is an output compare register

When a compare match occurs, the value in the buffer register for the corresponding channel is transferred to the timer general register.
This operation is illustrated in Figure 16.15.

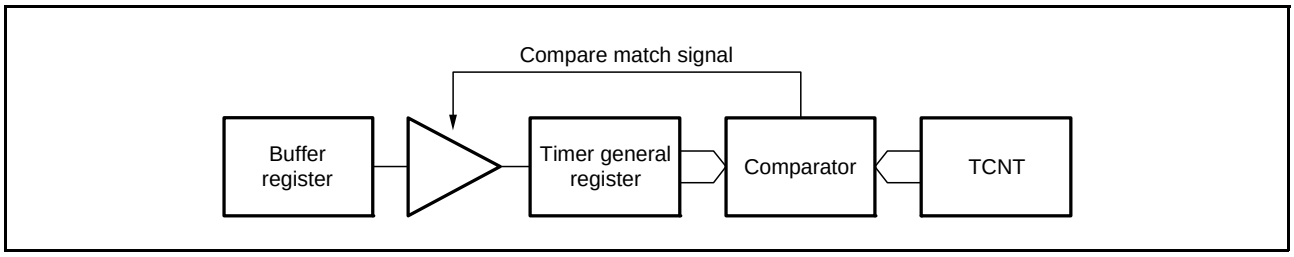


Figure 16.15 Compare Match Buffer Operation

- When TGR is an input capture register

When an input capture occurs, the value in TCNT is transferred to TGR and the value previously held in TGR is transferred to the buffer register.
This operation is illustrated in Figure 16.16.

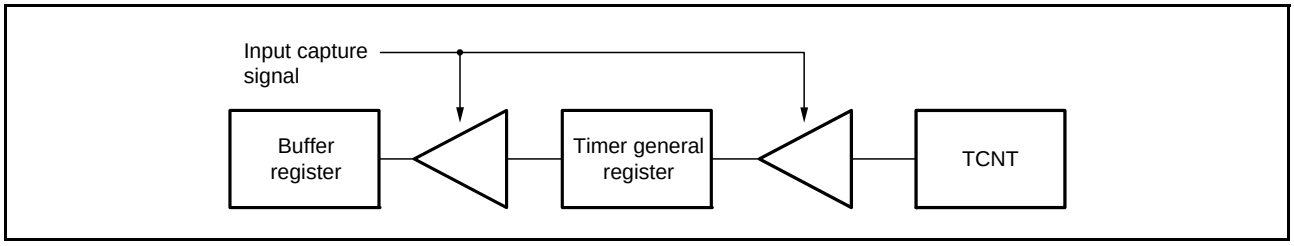


Figure 16.16 Input Capture Buffer Operation

(1) Example of Buffer Operation Setting Procedure

Figure 16.17 shows an example of the buffer operation setting procedure.

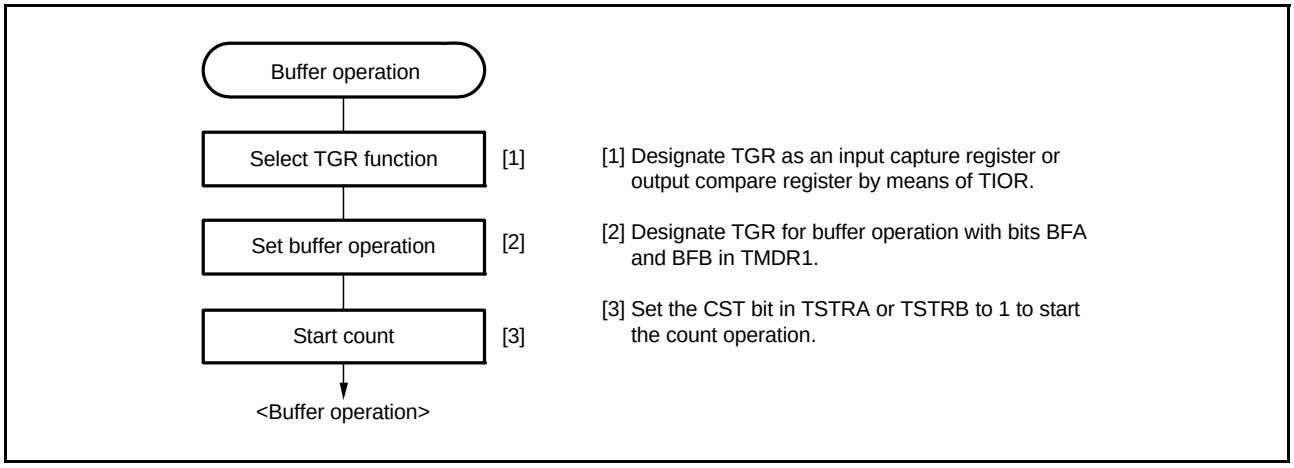


Figure 16.17 Example of Buffer Operation Setting Procedure

(2) Examples of Buffer Operation

(a) When TGR is an Output Compare Register

Figure 16.18 shows an operation example in which PWM mode 1 has been designated for MTU0, and buffer operation has been designated for TGRA and TGRC. The settings used in this example are TCNT clearing by compare match B, high output at compare match A, and low output at compare match B. In this example, the TTSA bit in TBTM is cleared to 0.

As buffer operation has been set, when compare match A occurs, the output changes and the value in buffer register TGRC is simultaneously transferred to timer general register TGRA. This operation is repeated each time compare match A occurs.

For details of PWM modes, see section 16.3.5, PWM Modes .

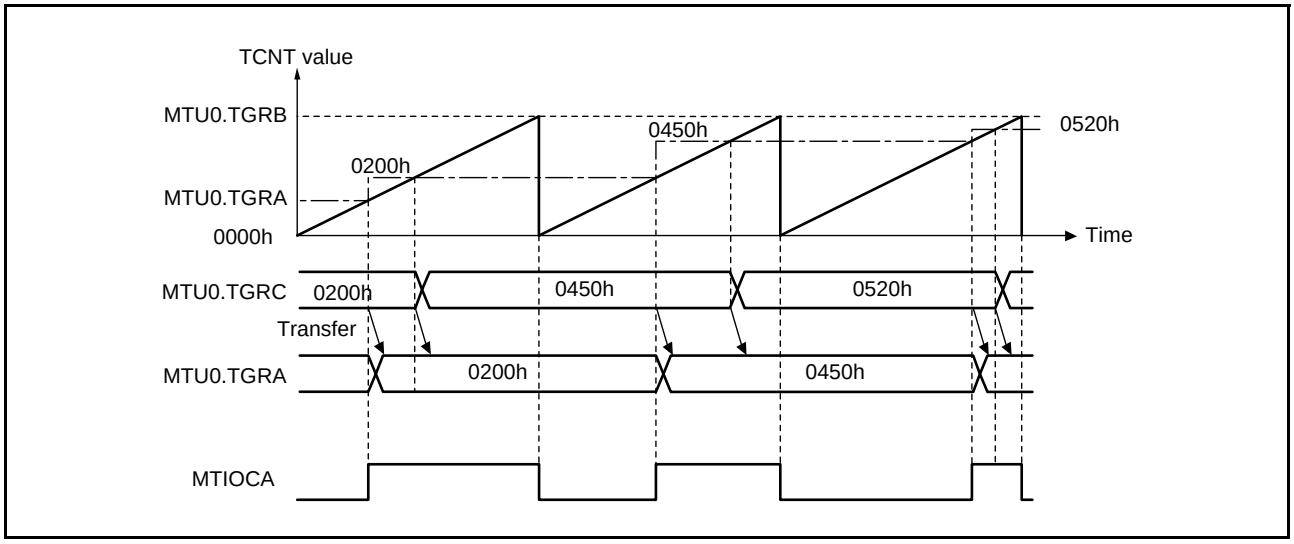


Figure 16.18 Example of Buffer Operation (1)

(b) When TGR is an Input Capture Register

Figure 16.19 shows an operation example in which TGRA has been designated as an input capture register, and buffer operation has been designated for TGRA and TGRC.
Counter clearing by TGRA input capture has been set for TCNT, and both rising and falling edges have been selected as the MTIOCA pin input capture input edge.
As buffer operation has been set, when the TCNT value is stored in TGRA upon occurrence of input capture A, the value previously stored in TGRA is simultaneously transferred to TGRC.

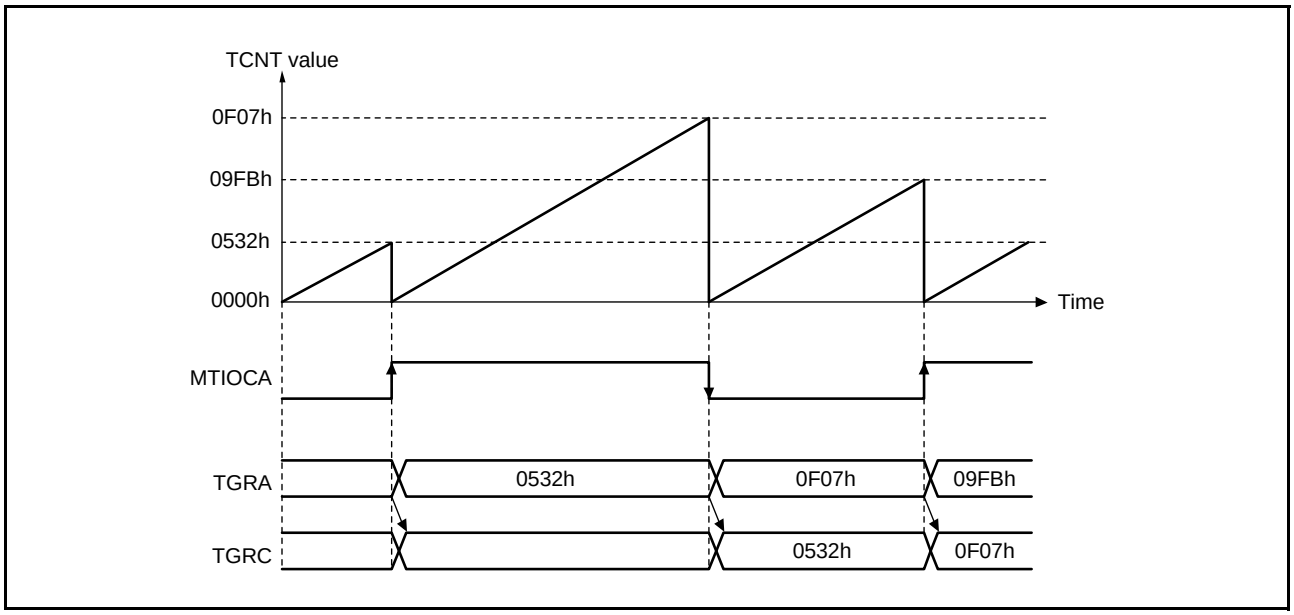


Figure 16.19 Example of Buffer Operation (2)

(3) Selecting Timing for Transfer from Buffer Registers to Timer General Registers in Buffer Operation

The timing for transfer from buffer registers to timer general registers can be selected in PWM mode 1 or 2 for MTU0 or in PWM mode 1 for MTU3, MTU4, MTU6, and MTU7 by setting the buffer operation transfer mode registers (MTUn.TBTM (n = 0, 3, 4, 6, or 7)). Either compare match (value after reset) or TCNT clearing can be selected for the transfer timing. TCNT clearing as transfer timing is one of the following cases.

- When TCNT overflows (FFFFh to 0000h)
- When 0000h is written to TCNT during counting
- When TCNT is cleared to 0000h under the condition specified in the CCLR[2:0] bits in TCR

Note: • TBTM must be modified only while TCNT stops.

Figure 16.20 shows an operation example in which PWM mode 1 is designated for MTU0 and buffer operation is designated for MTU0.TGRA and MTU0.TGRC. The settings used in this example are MTU0.TCNT clearing by compare match B, high output at compare match A, and low output at compare match B. The TTSA bit in MTU0.TBTM is set to 1.

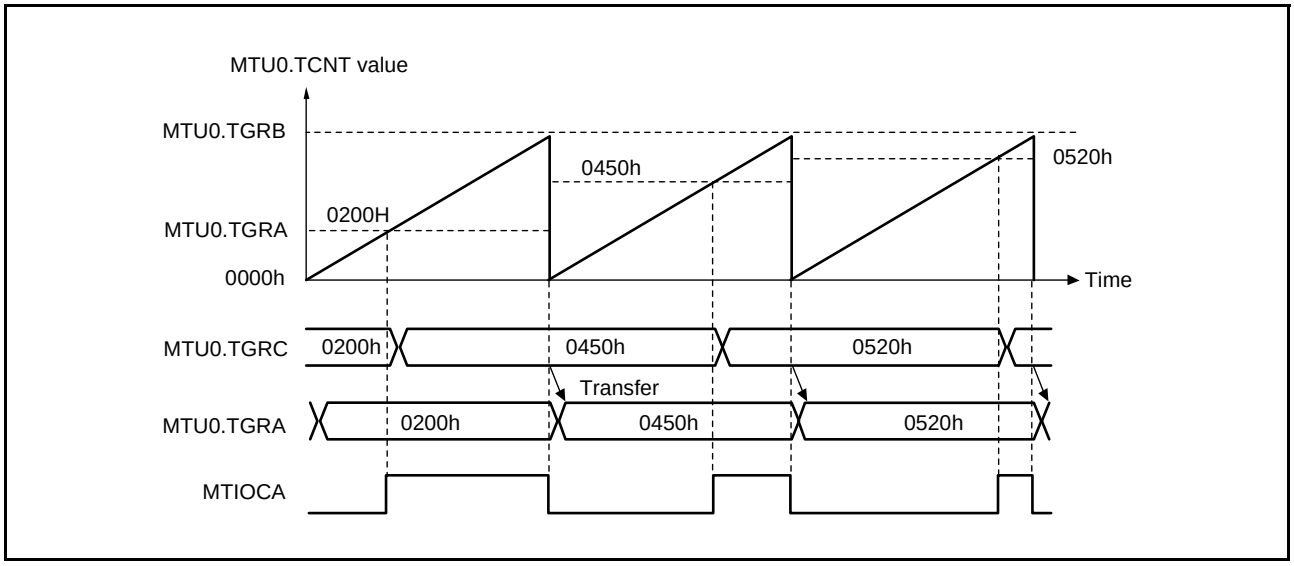


Figure 16.20 Example of Buffer Operation When MTU0.TCNT Clearing is Selected for MTU0.TGRC-to-MTU0.TGRA Transfer Timing

16.3.4 Cascaded Operation

In cascaded operation, two 16-bit counters in different channels are used together as a 32-bit counter.
This function works when overflow/underflow of MTU2.TCNT is selected as the counter clock for MTU1 through the TPSC[2:0] bits in TCR.
Underflow occurs only when the lower 16 bits of TCNT is in phase counting mode.
Table 16.59 shows the register combinations used in cascaded operation.

Note: • When phase counting mode is set for MTU1, the counter clock setting is invalid and the counters operate independently in phase counting mode.

Table 16.59 Cascaded Combinations

Combination	Upper 16 Bits	Lower 16 Bits
MTU and MTU2	MTU1.TCNT	MTU2.TCNT

For simultaneous input capture of MTU1.TCNT and MTU2.TCNT during cascaded operation, additional input capture input pins can be specified by the input capture control register (TICCR). The edge detected as an input capture condition is in the signal obtained by taking the logical OR of the levels being input on the original input pin and on the added input pin. Therefore, if one signal is at the high level, edges in the other will not be detected. For details, refer to (4) Cascaded Operation Example (c). For input capture in cascade connection, refer to section 16.6.21, Simultaneous Input Capture in MTU1.TCNT and MTU2.TCNT in Cascade Connection.
Table 16.60 shows the TICCR setting and input capture input pins.

Table 16.60 TICCR Setting and Input Capture Input Pins

Target Input Capture	TICCR Setting	Input Capture Input Pin
Input capture from MTU1.TCNT to MTU1.TGRA	I2AE bit = 0 (value after reset)	MTIOC1A
	I2AE bit = 1	MTIOC1A, MTIOC2A
Input capture from MTU1.TCNT to MTU1.TGRB	I2BE bit = 0 (value after reset)	MTIOC1B
	I2BE bit = 1	MTIOC1B, MTIOC2B
Input capture from MTU2.TCNT to MTU2.TGRA	I1AE bit = 0 (value after reset)	MTIOC2A
	I1AE bit = 1	MTIOC2A, MTIOC1A
Input capture from MTU2.TCNT to MTU2.TGRB	I1BE bit = 0 (value after reset)	MTIOC2B
	I1BE bit = 1	MTIOC2B, MTIOC1B

(1) Example of Cascaded Operation Setting Procedure

Figure 16.21 shows an example of the cascaded operation setting procedure.

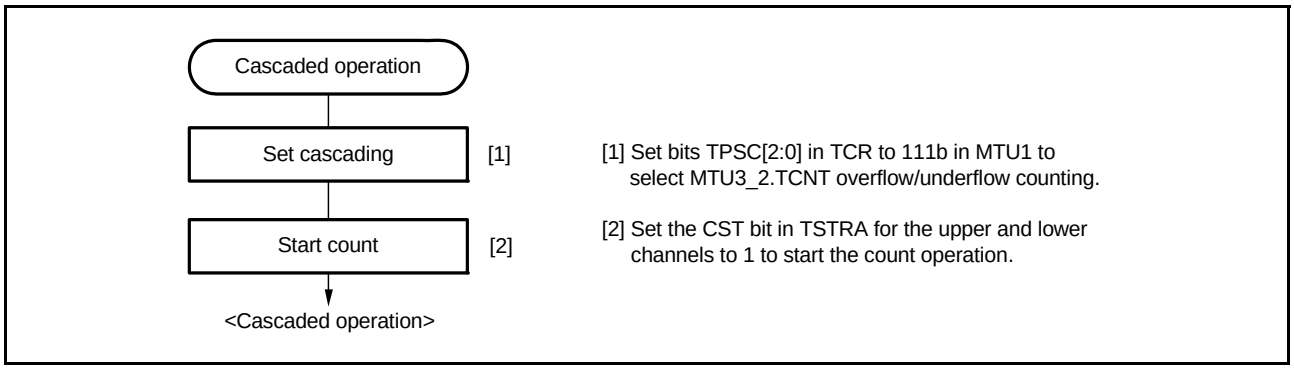


Figure 16.21 Cascaded Operation Setting Procedure

(2) Cascaded Operation Example (a)

Figure 16.22 illustrates the operation when MTU2.TCNT overflow/underflow counting has been set for MTU1.TCNT and phase counting mode has been designated for MTU2.
MTU1.TCNT is incremented by MTU2.TCNT overflow and decremented by MTU2.TCNT underflow.

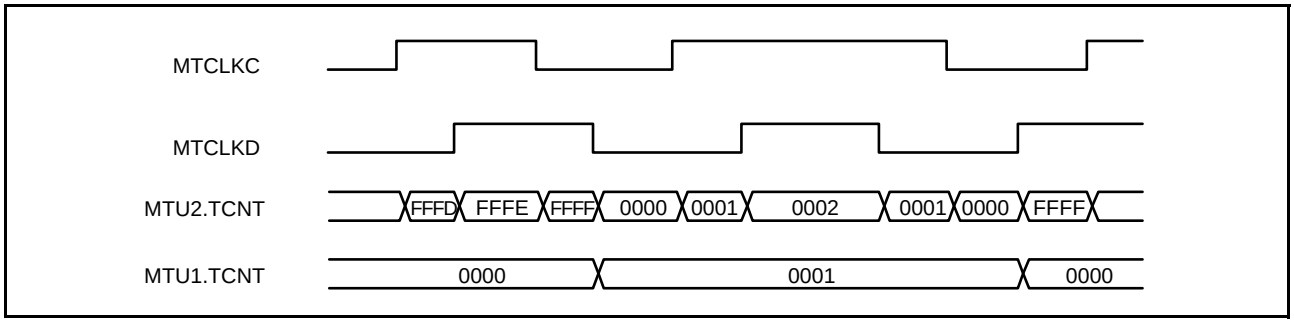


Figure 16.22 Cascaded Operation Example (a)

(3) Cascaded Operation Example (b)

Figure 16.23 illustrates the operation when MTU1.TCNT and MTU2.TCNT have been cascaded and the I2AE bit in TICCR has been set to 1 to include the MTIOC2A pin in the MTU1.TGRA input capture conditions. In this example, the MTU1.TIOR.IOA[3:0] bits have selected the MTIOC1A rising edge for the input capture timing while the MTU2.TIOR.IOA[3:0] bits have selected the MTIOC2A rising edge for the input capture timing.
Under these conditions, the rising edge of both MTIOC1A and MTIOC2A is used for the MTU1.TGRA input capture condition. For the MTU2.TGRA input capture condition, the MTIOC2A rising edge is used.

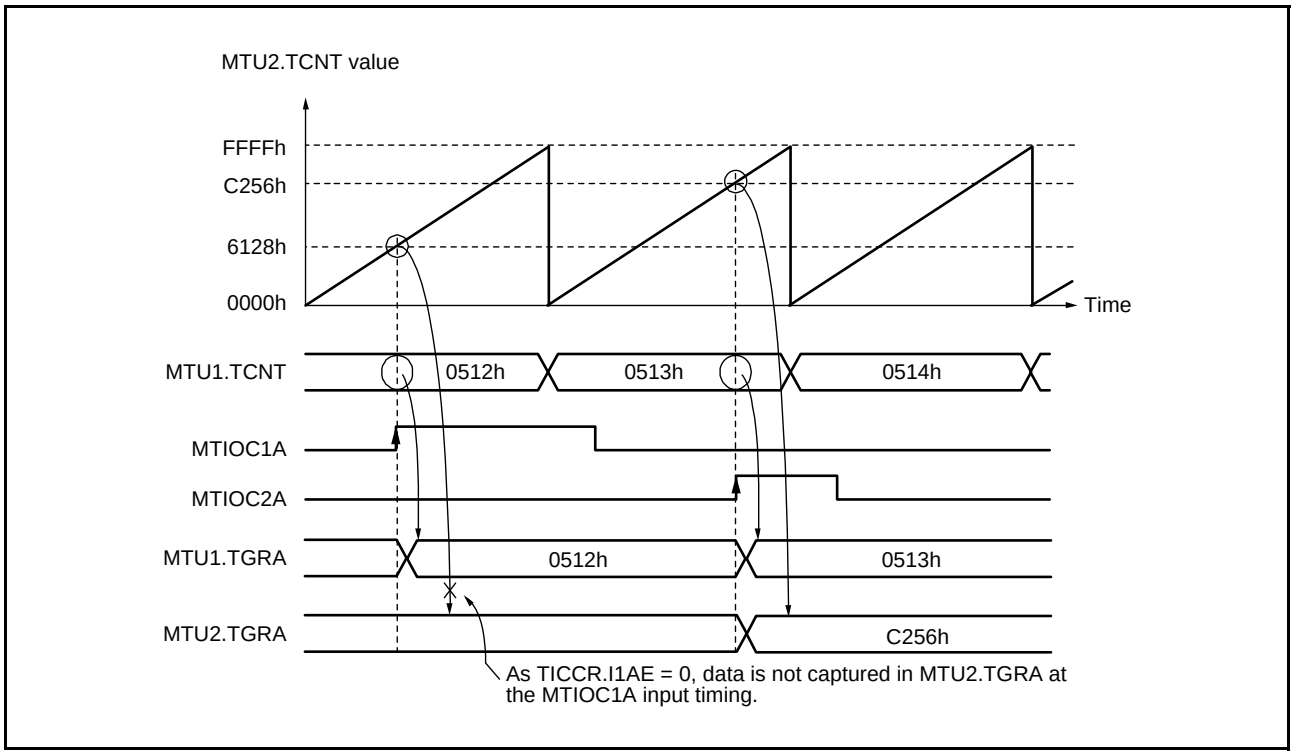
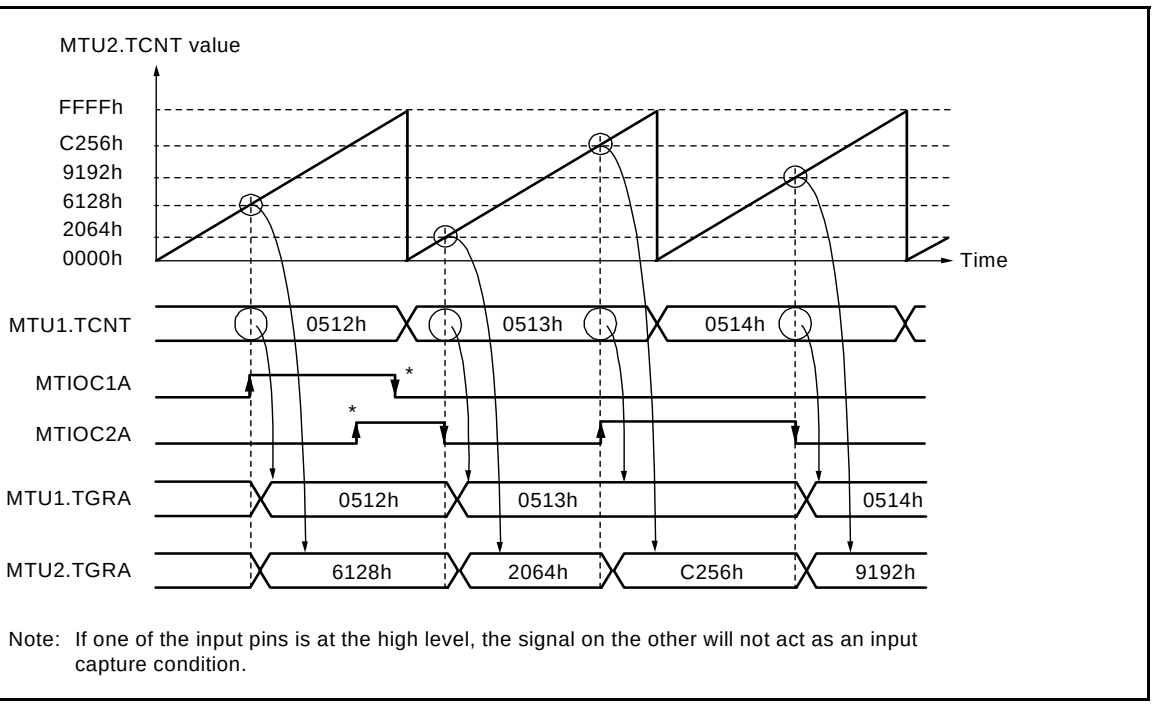


Figure 16.23 Cascaded Operation Example (b)

(4) Cascaded Operation Example (c)

Figure 16.24 illustrates the operation when MTU1.TCNT and MTU2.TCNT have been cascaded and the TICCR.I2AE and I1AE bits have been set to 1 to include the MTIOC2A and MTIOC1A pins in the MTU1.TGRA and MTU2.TGRA input capture conditions, respectively. In this example, the IOA[3:0] bits in both MTU1.TIOR and MTU2.TIOR have selected both the rising and falling edges for the input capture timing. Under these conditions, the ORed result of MTIOC1A and MTIOC2A input is used for the MTU1.TGRA and MTU2.TGRA input capture conditions.



Note: If one of the input pins is at the high level, the signal on the other will not act as an input capture condition.

Figure 16.24 Cascaded Operation Example (c)

(5) Cascaded Operation Example (d)

Figure 16.25 illustrates the operation when MTU1.TCNT and MTU2.TCNT have been cascaded and the TICCR.I2AE bit has been set to 1 to include the MTIOC2A pin in the MTU1.TGRA input capture conditions. In this example, the IOA[3:0] bits in MTU1.TIOR have selected occurrence of MTU0.TGRA compare match or input capture for the input capture timing while the IOA[3:0] bits in MTU2.TIOR have selected the MTIOC2A rising edge for the input capture timing.

Under these conditions, as MTU1.TIOR has selected occurrence of MTU0.TGRA compare match or input capture for the input capture timing, the MTIOC2A edge is not used for MTU1.TGRA input capture condition although the I2AE bit in TICCR has been set to 1.

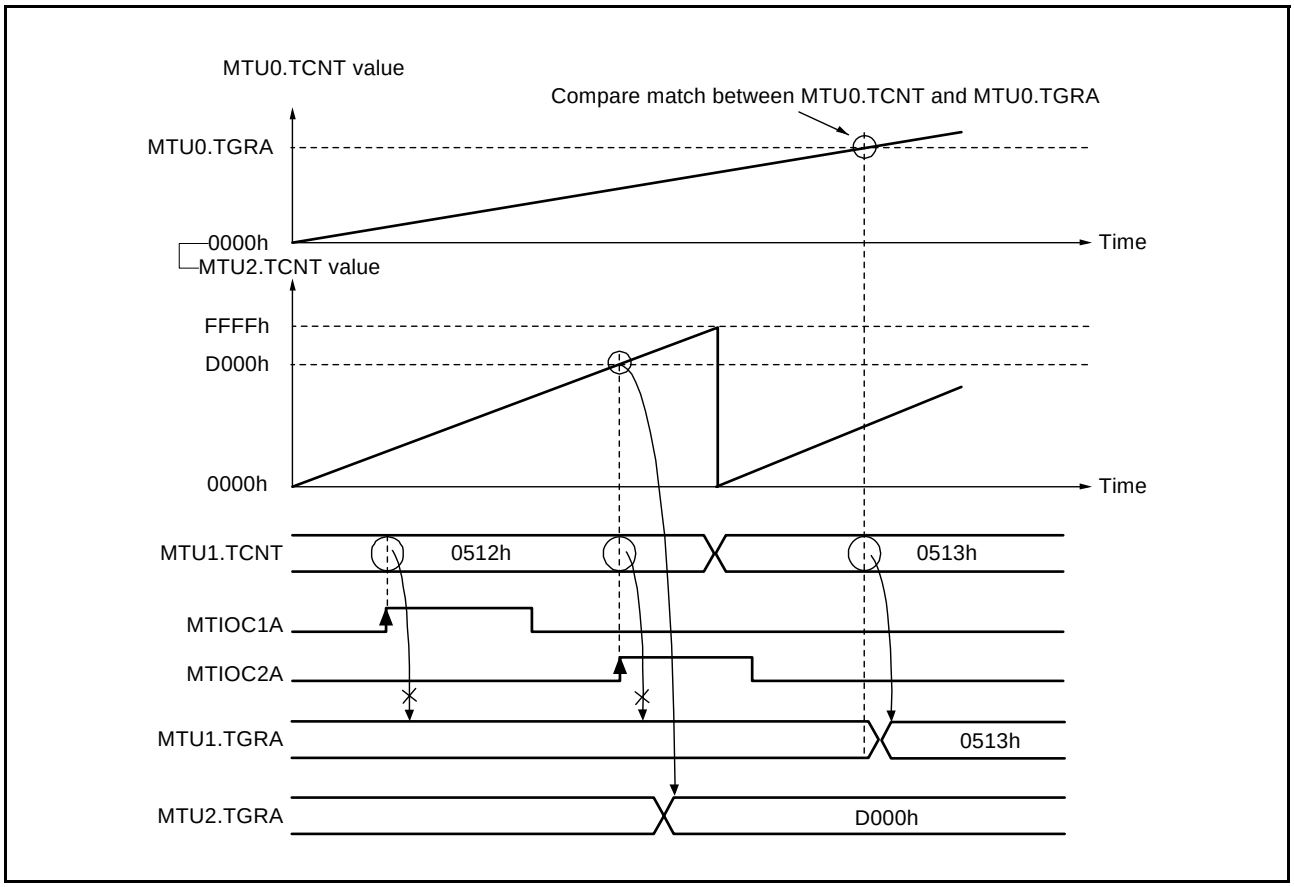


Figure 16.25 Cascaded Operation Example (d)

16.3.5 PWM Modes

PWM modes are provided to output PWM waveforms from the external pins. The output level can be selected as low, high, or toggle output in response to a compare match of each TGR.
PWM waveforms in the range of 0% to 100% duty cycle can be output according to the TGR settings.
By designating TGR compare match as the counter clearing source, the PWM cycle can be specified in that register.
Every channel can be set to PWM mode independently. Synchronous operation is also possible.
There are two PWM modes as described below.

(a) PWM Mode 1

PWM waveforms are output from the MTIOCA and MTIOCC pins by pairing TGRA with TGRB and TGRC with TGRD. The levels specified by the TIOR.IOA[3:0] and IOC[3:0] bits are output from the MTIOCA and MTIOCC pins at compare matches A and C, and the level specified by the TIOR.IOB[3:0] and IOD[3:0] bits are output at compare matches B and D. The initial output value is set in TGRA or TGRC. If the values set in paired TGRs are identical, the output value does not change even when a compare match occurs.
In PWM mode 1, up to 12 phases of PWM waveforms can be output.

(b) PWM Mode 2

PWM waveform output is generated using one TGR as the cycle register and the others as duty registers. The level specified in TIOR is output at compare matches. Upon counter clearing by a cycle register compare match, the initial value set in TIOR is output from each pin. If the values set in the cycle and duty registers are identical, the output value does not change even when a compare match occurs.

In PWM mode 2, up to eight phases of PWM waveforms can be output when using synchronous operation in combination.

The correspondence between PWM output pins and registers is shown in Table 16.61.

Table 16.61 PWM Output Registers and Output Pins

		Output Pins	
Channel	**Register**	**PWM Mode 1**	**PWM Mode 2**
MTU0	TGRA	MTIOC0A	MTIOC0A
	TGRB		MTIOC0B
	TGRC	MTIOC0C	MTIOC0C
	TGRD		MTIOC0D
MTU1	TGRA	MTIOC1A	MTIOC1A
	TGRB		MTIOC1B
MTU2	TGRA	MTIOC2A	MTIOC2A
	TGRB		MTIOC2B
MTU3	TGRA	MTIOC3A	Setting prohibited
	TGRB		
	TGRC	MTIOC3C	
	TGRD		
MTU4	TGRA	MTIOC4A	
	TGRB		
	TGRC	MTIOC4C	
	TGRD		
MTU6	TGRA	MTIOC6A	
	TGRB		
	TGRC	MTIOC6C	
	TGRD		
MTU7	TGRA	MTIOC7A	
	TGRB		
	TGRC	MTIOC7C	
	TGRD		

Note 1. In PWM mode 2, PWM waveform output is not possible for the TGR register in which the PWM cycle is set.

(1) Example of PWM Mode Setting Procedure

Figure 16.26 shows an example of the PWM mode setting procedure.

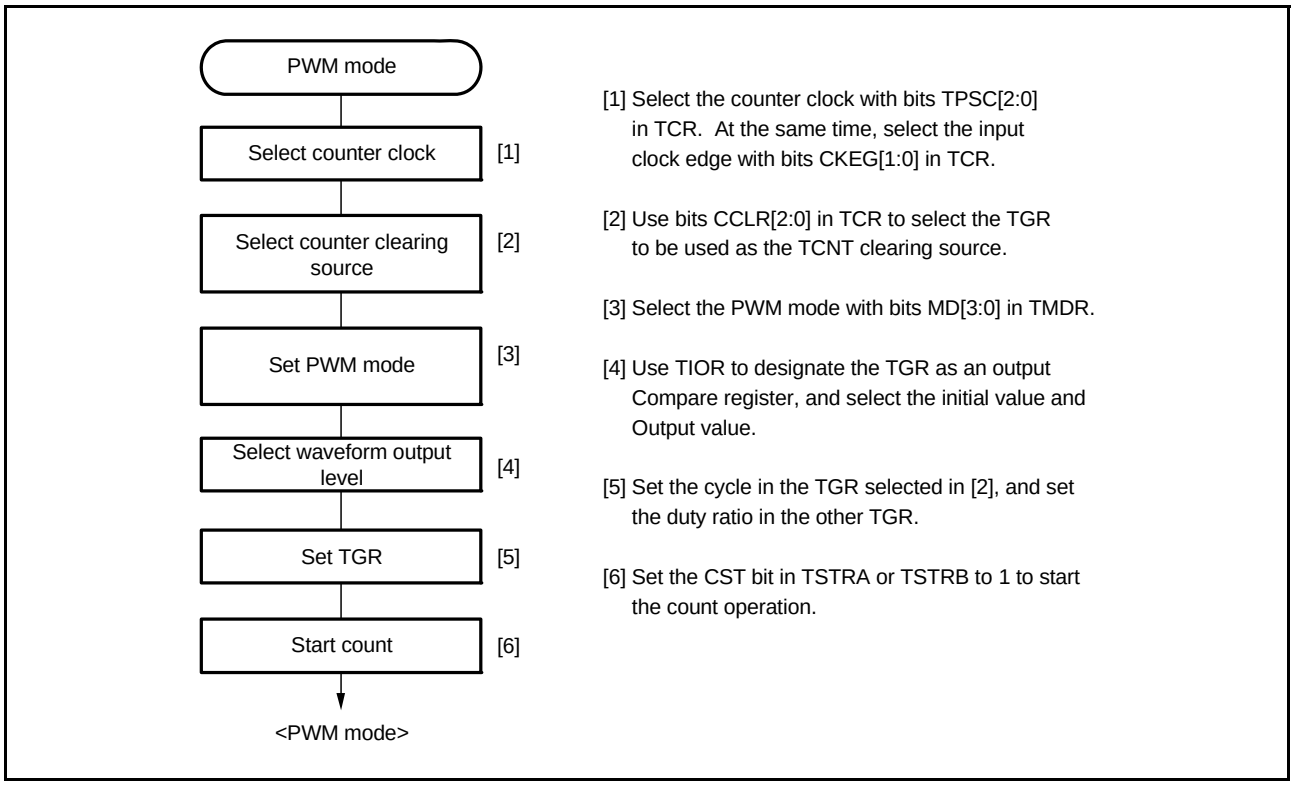


Figure 16.26 Example of PWM Mode Setting Procedure

(2) Examples of PWM Mode Operation

Figure 16.27 shows an example of operation in PWM mode 1.

In this example, TGRA compare match is set as the TCNT clearing source, 0 is set as the initial output value and output value for TGRA, and 1 is set as the output value for TGRB.

In this case, the value set in TGRA is used as the cycle, and the value set in TGRB is used as the duty ratio.

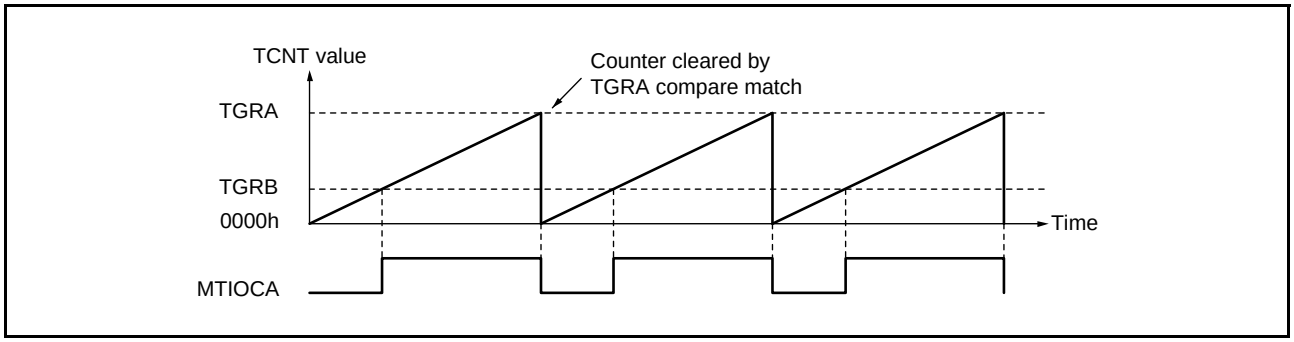


Figure 16.27 Example of PWM Mode 1 Operation

Figure 16.28 shows an example of operation in PWM mode 2.
In this example, synchronous operation is designated for MTU0 and MTU1, MTU1.TGRB compare match is set as the TCNT clearing source, and 0 is set as the initial output value and 1 as the output value for the other TGR registers (MTU0.TGRA to MTU0.TGRD and MTU1.TGRA), outputting 5-phase PWM waveforms.
In this case, the value set in MTU1.TGRB is used as the cycle, and the values set in the other TGRs are used as the duty ratio.

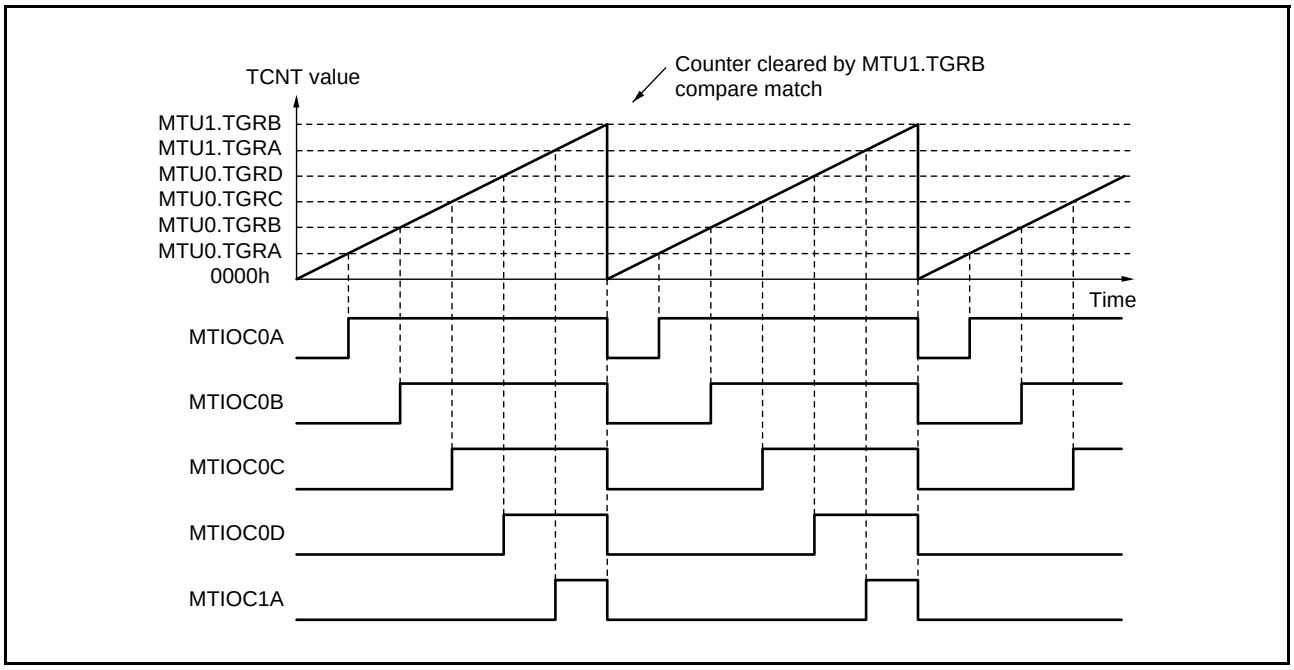


Figure 16.28 Example of PWM Mode 2 Operation

Figure 16.29 shows examples of PWM waveform output with 0% duty and 100% duty in PWM mode.

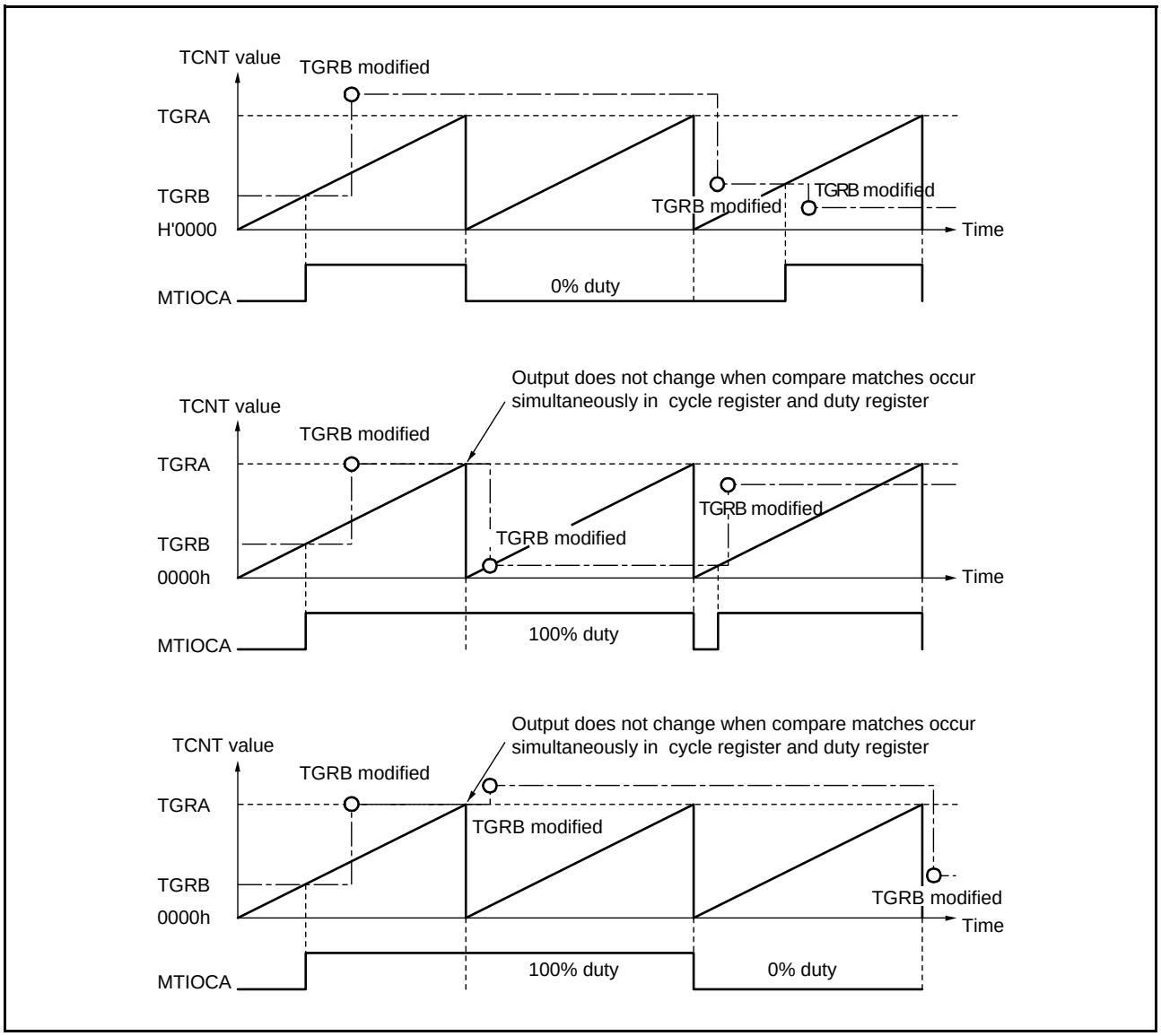


Figure 16.29 Examples of PWM Mode Operation (PWM Waveform Output with 0% Duty and 100% Duty)

16.3.6 Phase Counting Mode

In phase counting mode, the phase difference between two external input clocks is detected and TCNT is incremented or decremented accordingly. This mode can be set for MTU1 and MTU2.

When phase counting mode is specified, an external clock is selected as the counter input clock and TCNT operates as an up/down-counter regardless of the setting of bits TPSC[2:0] and bits CKEG[1:0] in TCR. However, the functions of bits CCLR[1:0] in TCR and of TIOR, TIER, and TGR are valid, and input capture/compare match and interrupt functions can be used.

This can be used for two-phase encoder pulse input.

If an overflow occurs while TCNT is counting up, the TCFV flag in TSR is set to 1. If an underflow occurs while TCNT is counting down, the TCFU flag is TSR is set to 1.

The TCFD flag in TSR is the count direction flag. Read the TCFD flag to check whether TCNT is counting up or down.

Table 16.62 shows the correspondence between external clock pins and channels.

Table 16.62 Clock Input Pins in Phase Counting Mode

	External Clock Input Pins	
Channel	**A-Phase**	**B-Phase**
When MTU1 is set to phase counting mode	MTCLKA	MTCLKB
When MTU2 is set to phase counting mode	MTCLKC	MTCLKD

(1) Example of Phase Counting Mode Setting Procedure

Figure 16.30 shows an example of the phase counting mode setting procedure.

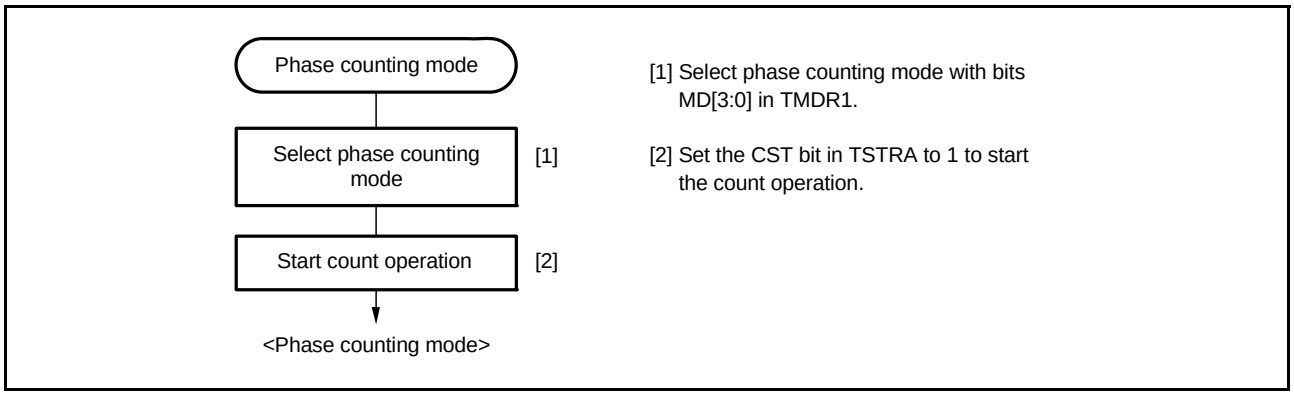


Figure 16.30 Example of Phase Counting Mode Setting Procedure

(2) Examples of Phase Counting Mode Operation

In phase counting mode, TCNT is incremented or decremented according to the phase difference between two external clocks. There are four modes according to the count conditions.

(a) Phase Counting Mode 1

Figure 16.31 shows an example of operation in phase counting mode 1, and Table 16.63 summarizes the TCNT up-/down-count conditions.

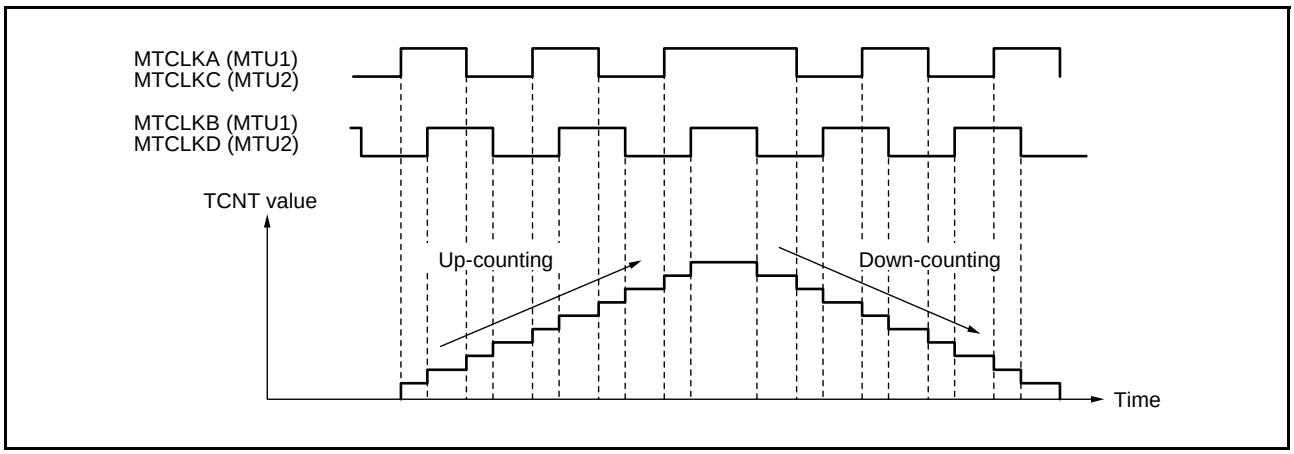


Figure 16.31 Example of Operation in Phase Counting Mode 1

Table 16.63 Up-/Down-Count Conditions in Phase Counting Mode 1

MTCLKA (MTU1) MTCLKC (MTU2)	MTCLKB (MTU1) MTCLKD (MTU2)	Operation
High	↑	Up-counting
Low	↓	
↑	Low	
↓	High	
High	↓	Down-counting
Low	↑	
↑	High	
↓	Low	

↑ : Rising edge

↓ : Falling edge

(b) Phase Counting Mode 2

Figure 16.32 shows an example of operation in phase counting mode 2, and Table 16.64 summarizes the TCNT up-/down-count conditions.

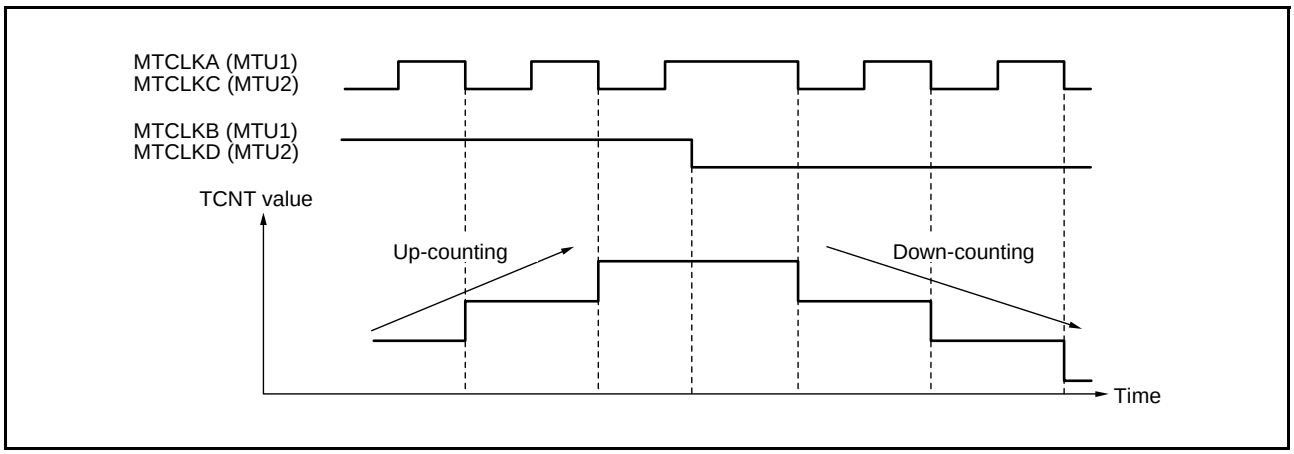


Figure 16.32 Example of Operation in Phase Counting Mode 2

Table 16.64 Up-/Down-Count Conditions in Phase Counting Mode 2

MTCLKA (MTU1) MTCLKC (MTU2)	MTCLKB (MTU1) MTCLKD (MTU2)	Operation
High	↑	Not counted (Don't care)
Low	↓	
↑	Low	
↓	High	Up-counting
High	↓	Not counted (Don't care)
Low	↑	
↑	High	
↓	Low	Down-counting

↑ : Rising edge

↓ : Falling edge

(c) Phase Counting Mode 3

Table 16.33 shows an example of operation in phase counting mode 3, and Table 16.65 summarizes the TCNT up-/down-count conditions.

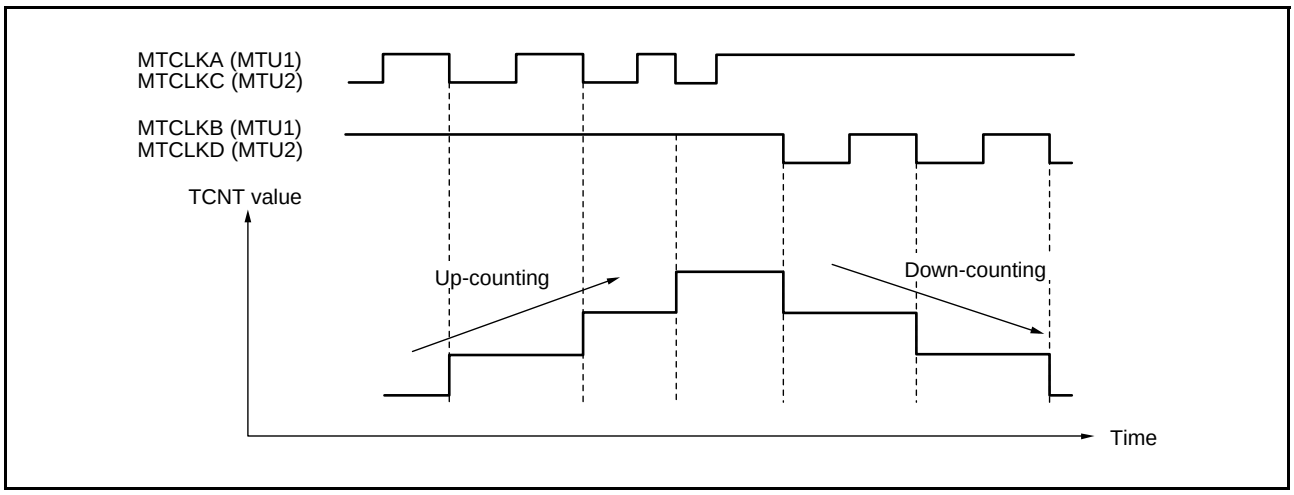


Figure 16.33 Example of Operation in Phase Counting Mode 3

Table 16.65 Up-/Down-Count Conditions in Phase Counting Mode 3

MTCLKA (MTU1) MTCLKC (MTU2)	MTCLKB (MTU1) MTCLKD (MTU2)	Operation
High	↑	Not counted (Don't care)
Low	↓	
↑	Low	
↓	High	Up-counting
High	↓	Down-counting
Low	↑	Not counted (Don't care)
↑	High	
↓	Low	

↑ : Rising edge

↓ : Falling edge

(a) Phase Counting Mode 4

Table 16.34 shows an example of operation in phase counting mode 4, and Table 16.66 summarizes the TCNT up-/down-count conditions.

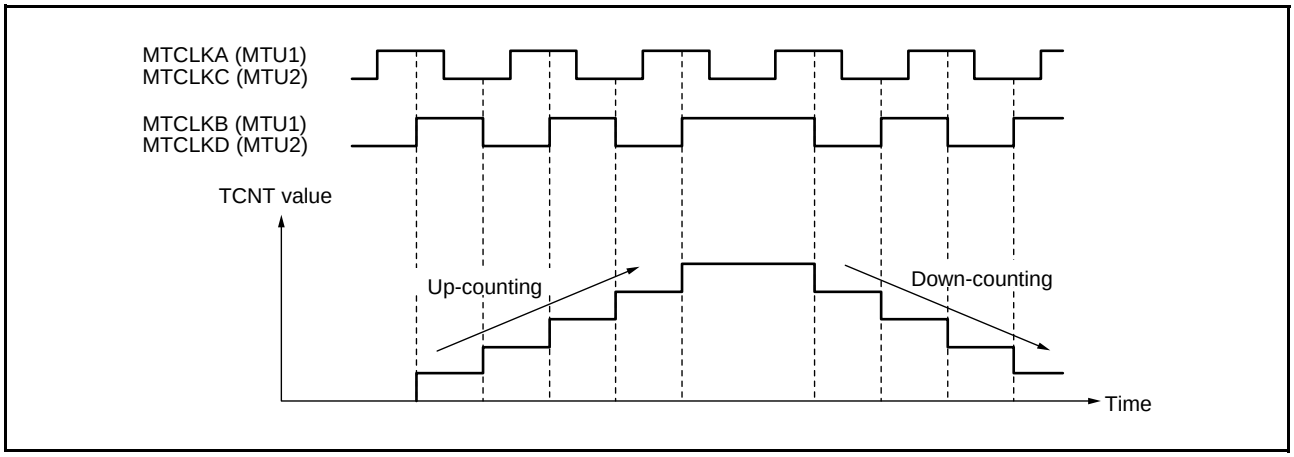


Figure 16.34 Example of Operation in Phase Counting Mode 4

Table 16.66 Up-/Down-Count Conditions in Phase Counting Mode 4

MTCLKA (MTU1) MTCLKC (MTU2)	MTCLKB (MTU1) MTCLKD (MTU2)	Operation
High	↑	Up-counting
Low	↓	
↑	Low	Not counted (Don't care)
↓	High	
High	↓	Down-counting
Low	↑	
↑	High	Not counted (Don't care)
↓	Low	

↑ : Rising edge

↓ : Falling edge

(3) Phase Counting Mode Application Example

Table 16.35 shows an example in which MTU1 is in phase counting mode, and MTU1 is coupled with MTU0 to input 2-phase encoder pulses of a servo motor in order to detect position or speed.
MTU1 is set to phase counting mode 1, and the encoder pulse A-phase and B-phase are input to MTCLKA and MTCLKB.
In MTU0, MTU0.TGRC compare match is specified as the TCNT clearing source and MTU0.TGRA and MTU0.TGRC are used for the compare match function and are set with the speed control cycle and position control cycle.
MTU0.TGRB is used for input capture, with MTU0.TGRB and MTU0.TGRD operating in buffer mode. The MTU1 counter input clock is designated as the MTU0.TGRB input capture source, and the widths of 2-phase encoder 4-multiplication pulses are detected.
MTU1.TGRA and MTU1.TGRB for MTU1 are designated for the input capture function and MTU0.TGRA and MTU0.TGRC compare matches in MTU0 are selected as the input capture sources to store the up/down-counter values for the control cycles.
This procedure enables the accurate detection of position and speed.

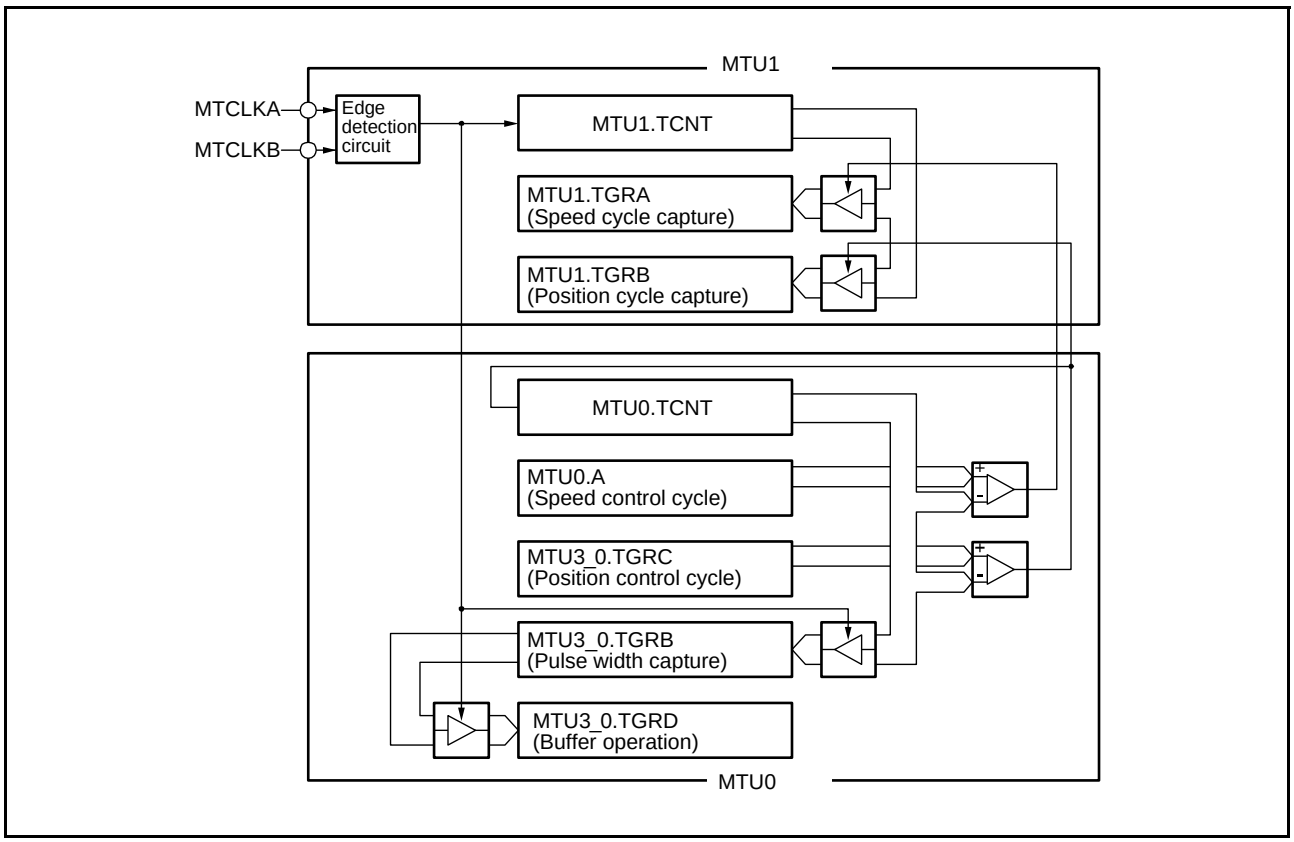


Figure 16.35 Phase Counting Mode Application Example

16.3.7 Reset-Synchronized PWM Mode

In the reset-synchronized PWM mode, three phases of positive and negative PWM waveforms (six phases in total) that share a common wave transition point can be output by combining MTU3 and MTU4, and MTU6 and MTU7.
When set for reset-synchronized PWM mode, the MTIOC3B, MTIOC3D, MTIOC4A, MTIOC4C, MTIOC4B, MTIOC4D, MTIOC6B, MTIOC6D, MTIOC7A, MTIOC7C, MTIOC7B, and MTIOC7D pins function as PWM output pins and timer counters 3 and 6 (MTU3.TCNT and MTU6.TCNT) functions as an up-counter.
Table 16.67 shows the PWM output pins used. Table 16.68 shows the settings of the registers.

Table 16.67 Output Pins for Reset-Synchronized PWM Mode

Channel	Output Pin	Description
MTU3	MTIOC3B	PWM output pin 1
	MTIOC3D	PWM output pin 1' (negative-phase waveform of PWM output 1)
MTU4	MTIOC4A	PWM output pin 2
	MTIOC4C	PWM output pin 2' (negative-phase waveform of PWM output 2)
	MTIOC4B	PWM output pin 3
	MTIOC4D	PWM output pin 3' (negative-phase waveform of PWM output 3)
MTU6	MTIOC6B	PWM output pin 4
	MTIOC6D	PWM output pin 4' (negative-phase waveform of PWM output 4)
MTU7	MTIOC7A	PWM output pin 5
	MTIOC7C	PWM output pin 5' (negative-phase waveform of PWM output 5)
	MTIOC7B	PWM output pin 6
	MTIOC7D	PWM output pin 6' (negative-phase waveform of PWM output 6)

Table 16.68 Register Settings for Reset-Synchronized PWM Mode

Register	Setting
MTU3.TCNT	Initial setting (0000h)
MTU4.TCNT	Initial setting (0000h)
MTU3.TGRA	Set the count cycle for MTU3.TCNT
MTU3.TGRB	Set the transition point of the PWM waveform to be output from the MTIOC3B and MTIOC3D pins
MTU4.TGRA	Set the transition point of the PWM waveform to be output from the MTIOC4A and MTIOC4C pins
MTU4.TGRB	Set the transition point of the PWM waveform to be output from the MTIOC4B and MTIOC4D pins
MTU6.TCNT	Initial setting (0000h)
MTU7.TCNT	Initial setting (0000h)
MTU6.TGRA	Set the count cycle for MTU6.TCNT
MTU6.TGRB	Set the transition point of the PWM waveform to be output from the MTIOC6B and MTIOC6D pins
MTU7.TGRA	Set the transition point of the PWM waveform to be output from the MTIOC7A and MTIOC7C pins
MTU7.TGRB	Set the transition point of the PWM waveform to be output from the MTIOC7B and MTIOC7D pins

(1) Example of Procedure for Setting Reset-Synchronized PWM Mode

Figure 16.36 shows an example of procedure for setting the reset-synchronized PWM mode.

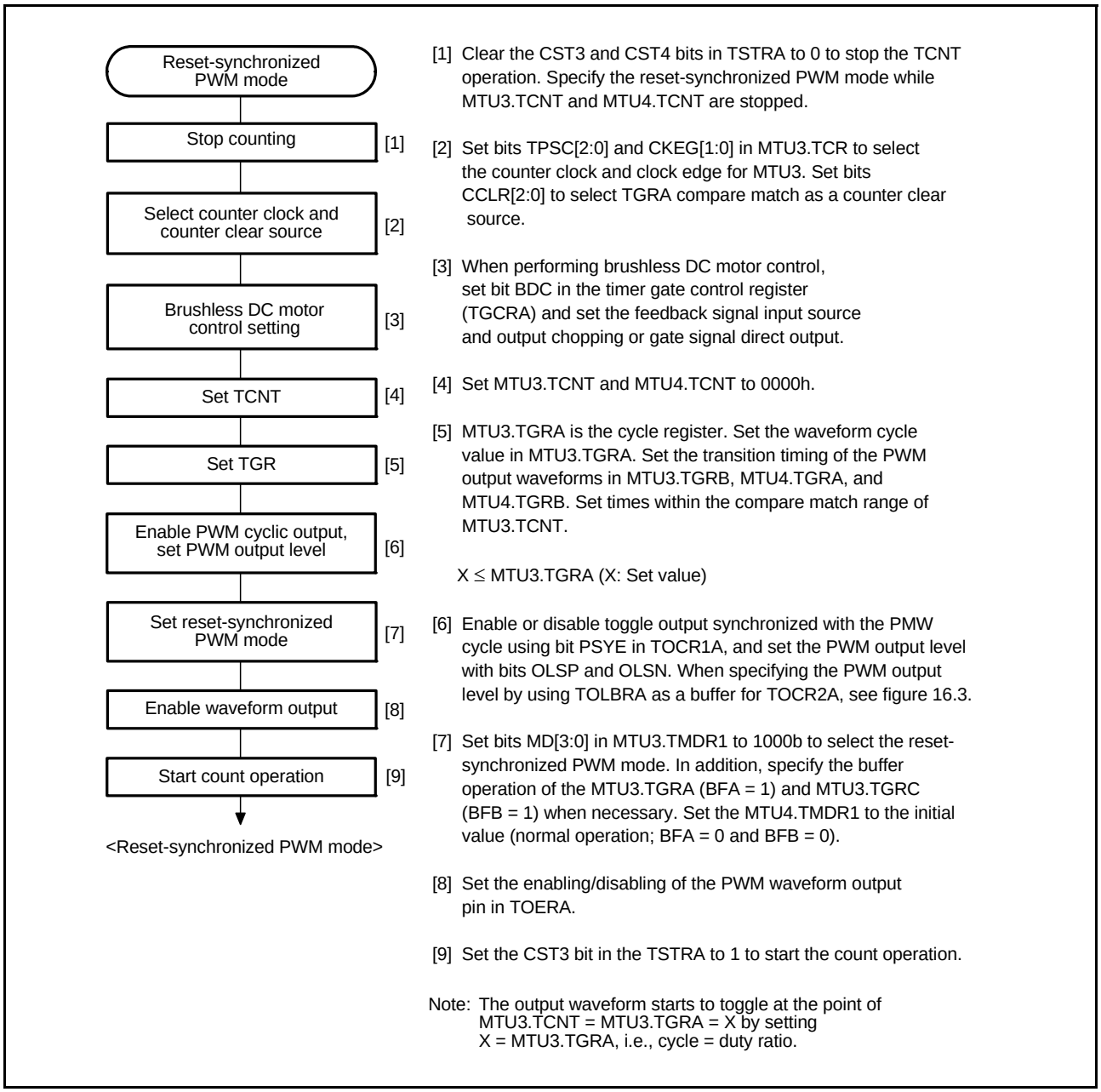


Figure 16.36 Procedure for Selecting Reset-Synchronized PWM Mode

(2) Example of Reset-Synchronized PWM Mode Operation

Figure 16.37 shows an example of operation in the reset-synchronized PWM mode.
MTU3.TCNT and MTU4.TCNT (MTU6.TCNT and MTU7.TCNT) operate as up-counters. The counters are cleared when a compare match occurs between MTU3.TCNT (MTU6.TCNT) and MTU3.TGRA (MTU6.TGRA), and then begin incrementing from 0000h. The output from the PWM pins toggles every time a compare match occurs in MTU3.TGRB (MTU6.TGRB), MTU4.TGRA (MTU7.TGRA), and MTU4.TGRB (MTU7.TGRB) and the counters are cleared.

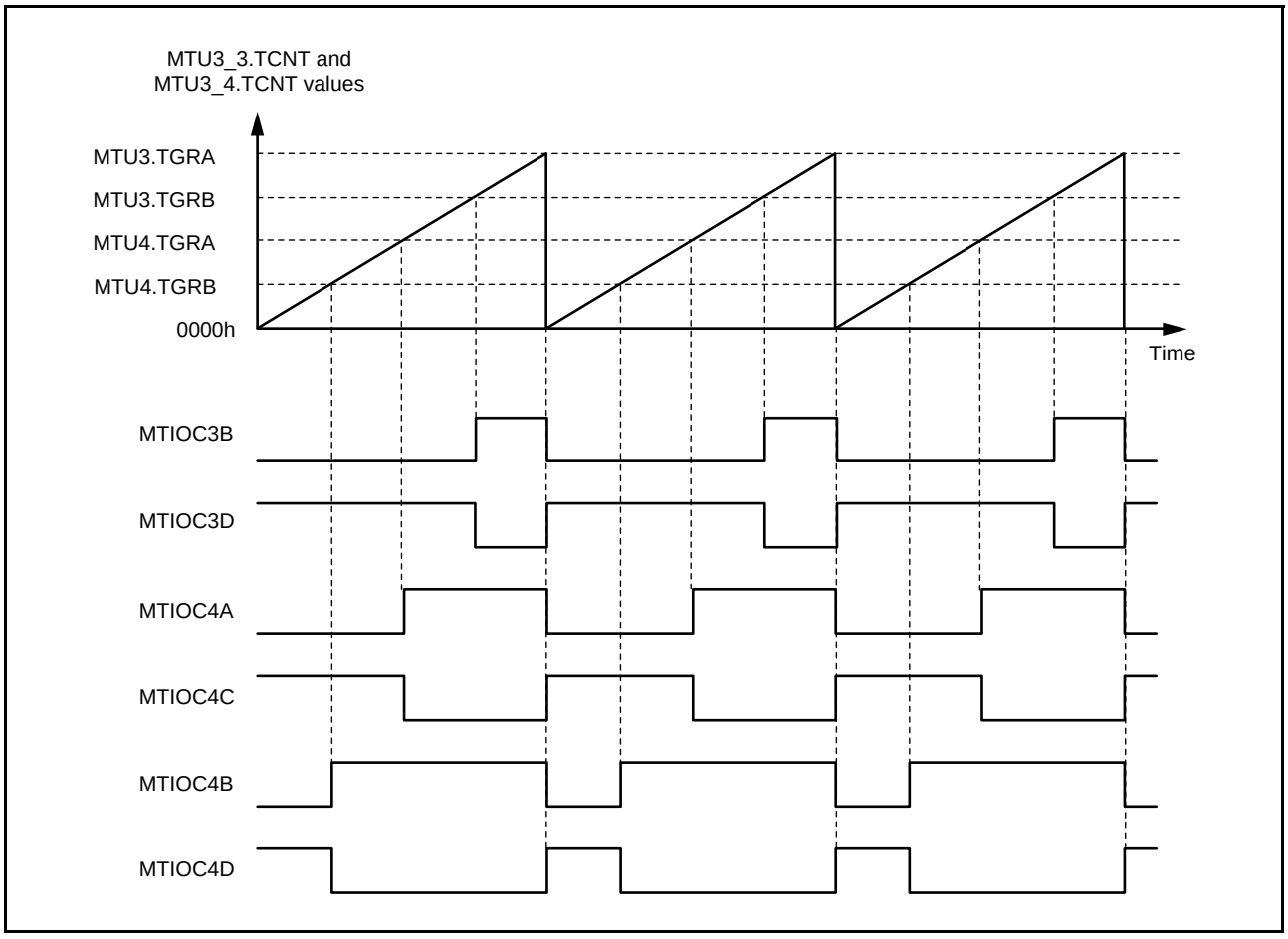


Figure 16.37 Example of Reset-Synchronized PWM Mode Operation (When TOCR1A's OLSN = 1 and OLSP = 1 in MTU3 and MTU4)

16.3.8 Complementary PWM Mode

In complementary PWM mode, three phases of non-overlapping positive and negative PWM waveforms (six phases in total) can be output by combining MTU3 and MTU4, and MTU6 and MTU7. PWM waveforms without non-overlapping interval are also available.

In complementary PWM mode, MTIOC3B, MTIOC3D, MTIOC4A, MTIOC4B, MTIOC4C, MTIOC4D, MTIOC6B, MTIOC6D, MTIOC7A, MTIOC7B, MTIOC7C, and MTIOC7D pins function as PWM output pins, and the MTIOC3A and MTIOC6A pins can be set for toggle output synchronized with the PWM cycle.

MTU3.TCNT, MTU4.TCNT, MTU6.TCNT, and MTU7.TCNT function as up/down-counters.

Table 16.68 shows the PWM output pins used. Table 16.70 shows the settings of the registers used.

A function to directly cut off the PWM output by using an external signal is supported as a port function.

Table 16.69 Output Pins for Complementary PWM Mode

Channel	Output Pin	Description
MTU3	MTIOC3A	Toggle output synchronized with PWM cycle (or I/O port)
	MTIOC3B	PWM output pin 1
	MTIOC3C	I/O port*1
	MTIOC3D	PWM output pin 1' (non-overlapping negative-phase waveform of PWM output 1; PWM output without non-overlapping interval is also available)
MTU4	MTIOC4A	PWM output pin 2
	MTIOC4C	PWM output pin 2' (non-overlapping negative-phase waveform of PWM output 2; PWM output without non-overlapping interval is also available)
	MTIOC4B	PWM output pin 3
	MTIOC4D	PWM output pin 3' (non-overlapping negative-phase waveform of PWM output 3; PWM output without non-overlapping interval is also available)
MTU6	MTIOC6A	Toggle output synchronized with PWM cycle (or I/O port)
	MTIOC6B	PWM output pin 4
	MTIOC6C	I/O port*1
	MTIOC6D	PWM output pin 4' (non-overlapping negative-phase waveform of PWM output 4; PWM output without non-overlapping interval is also available)
MTU7	MTIOC7A	PWM output pin 5
	MTIOC7C	PWM output pin 5' (non-overlapping negative-phase waveform of PWM output 5; PWM output without non-overlapping interval is also available)
	MTIOC7B	PWM output pin 6
	MTIOC7D	PWM output pin 6' (non-overlapping negative-phase waveform of PWM output 6; PWM output without non-overlapping interval is also available)

Note 1. Avoid setting the MTIOC3C and MTIOC6C pins as timer I/O pins in complementary PWM mode.

Table 16.70 Register Settings for Complementary PWM Mode

Channel	Counter/ Register	Description	Read/Write from CPU
MTU3	TCNT	Starts up-counting from the value set in the dead time register	Maskable by TRWERA setting *1
	TGRA	Set MTU3.TCNT upper limit value (1/2 carrier cycle + dead time)	Maskable by TRWERA setting *1
	TGRB	PWM output 1 compare register	Maskable by TRWERA setting*1
	TGRC	MTU3.TGRA buffer register	Always readable/writable
	TGRD	PWM output 1/MTU3.TGRB buffer register	Always readable/writable
	TGRE	MTU3.TGRB buffer register B (when double buffer function is used)	Always readable/writable
MTU4	TCNT	Starts up-counting after being initialized to 0000h	Maskable by TRWERA setting*1
	TGRA	PWM output 2 compare register	Maskable by TRWERA setting*1
	TGRB	PWM output 3 compare register	Maskable by TRWERA setting*1
	TGRC	PWM output 2/MTU4.TGRA buffer register	Always readable/writable
	TGRD	PWM output 3/MTU4.TGRB buffer register	Always readable/writable
	TGRE	MTU4.TGRA buffer register B (when double buffer function is used)	Always readable/writable
	TGRF	MTU4.TGRB buffer register B (when double buffer function is used)	Always readable/writable
MTU6	TCNT	Starts up-counting from the value set in the dead time register	Maskable by TRWERB setting*2
	TGRA	Set MTU6.TCNT upper limit value (1/2 carrier cycle + dead time)	Maskable by TRWERB setting *2
	TGRB	PWM output 4 compare register	Maskable by TRWERB setting*2
	TGRC	MTU6.TGRA buffer register	Always readable/writable
	TGRD	PWM output 4/MTU6.TGRB buffer register	Always readable/writable
	TGRE	MTU6.TGRB buffer register B (when double buffer function is used)	Always readable/writable
MTU7	TCNT	Starts up-counting after being initialized to 0000h	Maskable by TRWERB setting*2
	TGRA	PWM output 5 compare register	Maskable by TRWERB setting*2
	TGRB	PWM output 6 compare register	Maskable by TRWERB setting*2
	TGRC	PWM output 5/MTU7.TGRA buffer register	Always readable/writable
	TGRD	PWM output 6/MTU7.TGRB buffer register	Always readable/writable
	TGRE	MTU7.TGRA buffer register B (when double buffer function is used)	Always readable/writable
	TGRF	MTU7.TGRB buffer register B (when double buffer function is used)	Always readable/writable

Note 1. Access can be enabled or disabled according to the setting in TRWERA (timer read/write enable register A).
Note 2. Access can be enabled or disabled according to the setting in TRWERB (timer read/write enable register B).

Table 16.71 Register Settings for Complementary PWM Mode

Channel	Counter/ Register	Description	Read/Write from CPU
Timer dead time data register A (TDDRA)		Set MTU4.TCNT and MTU3.TCNT offset value (dead time value)	Maskable by TRWERA setting *1
Timer dead time data register B (TDDRB)		Set MTU7.TCNT and MTU6.TCNT offset value (dead time value)	Maskable by TRWERB setting *2
Timer cycle data register A (TCDRA)		Set MTU4.TCNT upper limit value (1/2 carrier cycle)	Maskable by TRWERA setting *1
Timer cycle data register B (TCDRB)		Set MTU7.TCNT upper limit value (1/2 carrier cycle)	Maskable by TRWERB setting *2
Timer cycle buffer register A (TCBRA)		TCDRA buffer register	Always readable/writable
Timer cycle buffer register B (TCBRB)		TCDRB buffer register	Always readable/writable
Subcounter A (TCNTSA)		Subcounter A for dead time generation	Read-only
Subcounter B (TCNTSB)		Subcounter B for dead time generation	Read-only
Temporary register 1A (TEMP1A)		PWM output 1/MTU3.TGRB temporary register A	Not readable/writable
Temporary register 1B (TEMP1B)		PWM output 1/MTU3.TGRB temporary register B (when double buffer function is used)	Not readable/writable
Temporary register 2A (TEMP2A)		PWM output 2/MTU4.TGRA temporary register A	Not readable/writable
Temporary register 2B (TEMP2B)		PWM output 2/MTU4.TGRA temporary register B (when double buffer function is used)	Not readable/writable
Temporary register 3A (TEMP3A)		PWM output 3/MTU4.TGRB temporary register A	Not readable/writable
Temporary register 3B (TEMP3B)		PWM output 3/MTU4.TGRB temporary register B (when double buffer function is used)	Not readable/writable
Temporary register 4A (TEMP4A)		PWM output 4/MTU6.TGRB temporary register A	Not readable/writable
Temporary register 4B (TEMP4B)		PWM output 4/MTU6.TGRB temporary register B (when double buffer function is used)	Not readable/writable
Temporary register 5A (TEMP5A)		PWM output 5/MTU7.TGRA temporary register A	Not readable/writable
Temporary register 5B (TEMP5B)		PWM output 5/MTU7.TGRA temporary register B (when double buffer function is used)	Not readable/writable
Temporary register 6A (TEMP6A)		PWM output 6/MTU7.TGRB temporary register A	Not readable/writable
Temporary register 6B (TEMP6B)		PWM output 6/MTU7.TGRB temporary register B (when double buffer function is used)	Not readable/writable

Note 1. Access can be enabled or disabled according to the setting in TRWERA (timer read/write enable register A).
Note 2. Access can be enabled or disabled according to the setting in TRWERB (timer read/write enable register B).

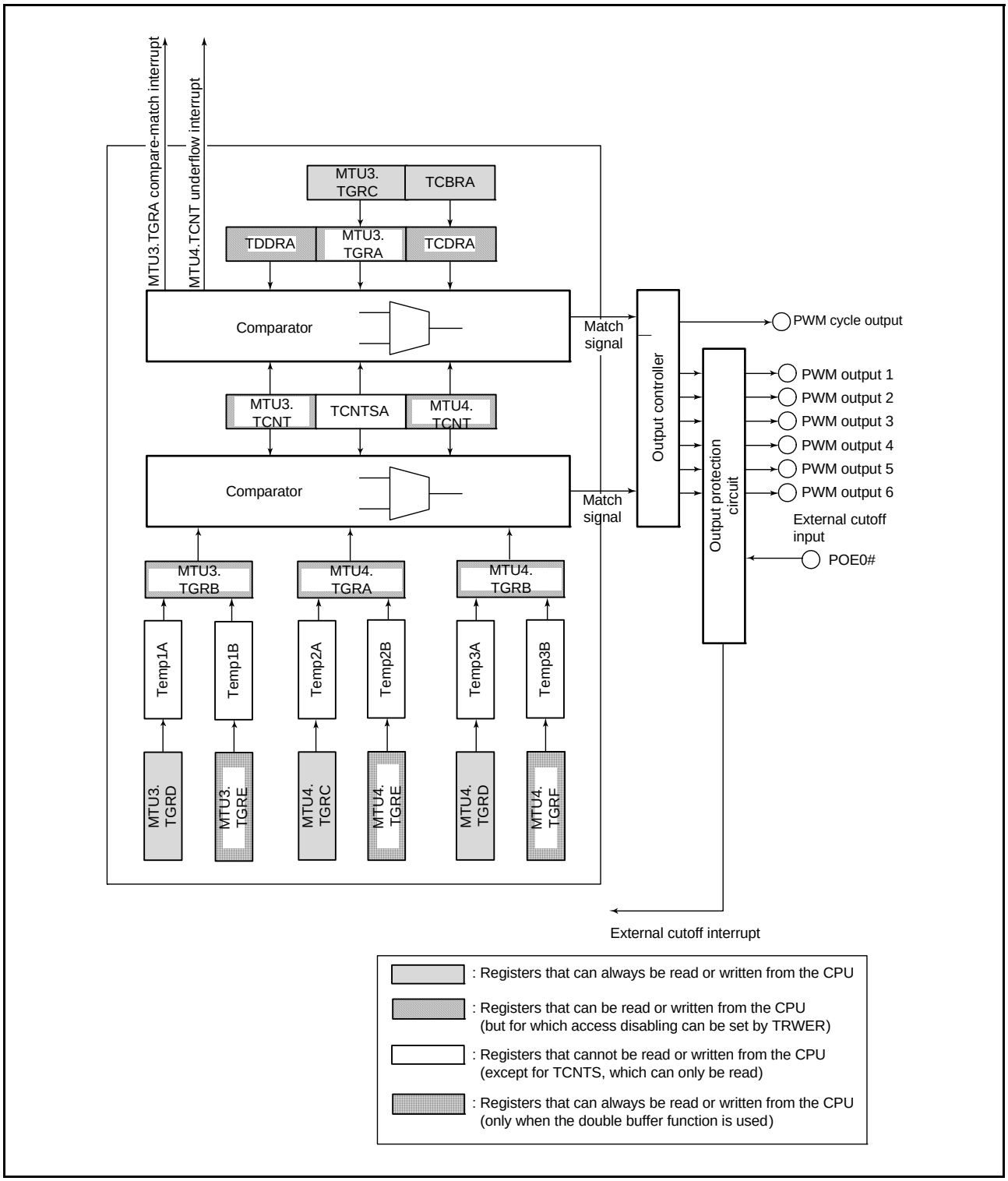


Figure 16.38 Block Diagram of MTU3 and MTU4 in Complementary PWM Mode

(1) Example of Complementary PWM Mode Setting Procedure

Figure 16.39 shows an example of the complementary PWM mode setting procedure.

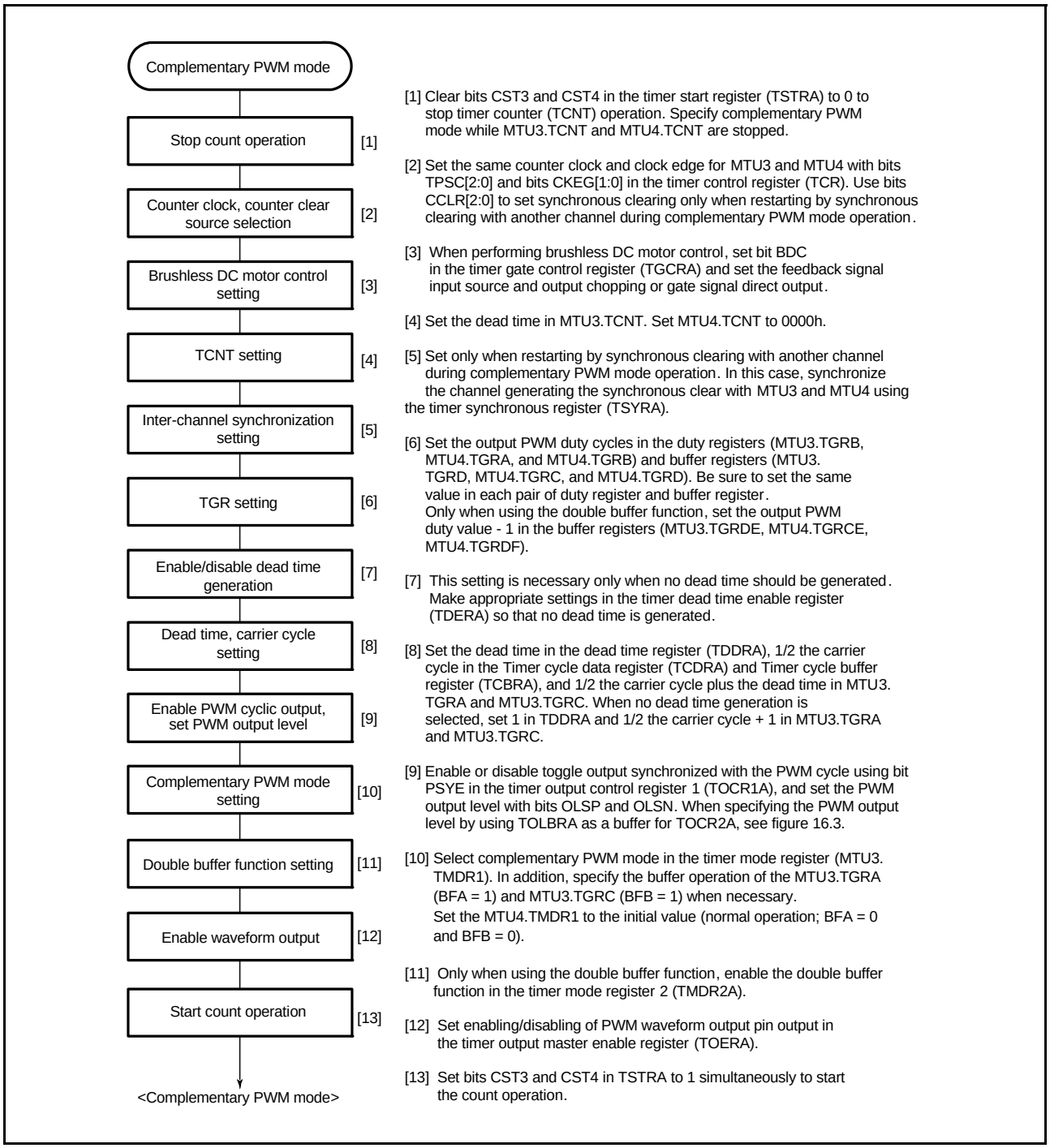


Figure 16.39 Example of Complementary PWM Mode Setting Procedure

(2) Outline of Complementary PWM Mode Operation

In complementary PWM mode, six phases of PWM waveforms can be output. Figure 16.40 illustrates counter operation in complementary PWM mode (MTU3 and MTU4), and Figure 16.41 shows an example of operation in complementary PWM mode.

(a) Counter Operation

In complementary PWM mode, three counters—MTU3.TCNT, MTU4.TCNT, and TCNTSA (MTU6.TCNT, MTU7.TCNT, and TCNTSB)—in each unit perform up-/down-count operations.
MTU3.TCNT (MTU6.TCNT) is automatically initialized to the value set in TDDRA (TDDRB) when complementary PWM mode is selected and the CST bit in TSTRA (TSTRB) is 0. When the CST bit is set to 1, MTU3.TCNT (MTU6.TCNT) counts up to the value set in MTU3.TGRA (MTU6.TGRA), then switches to down-counting when it matches MTU3.TGRA (MTU6.TGRA). When the MTU4.TCNT (MTU7.TCNT) value matches 0000h, MTU3.TCNT (MTU6.TCNT) switches to up-counting, and the operation is repeated in this way.
MTU4.TCNT (MTU7.TCNT) should be initialized to 0000h after a reset. When the CST bit is set to 1, MTU4.TCNT (MTU7.TCNT) counts up in synchronization with MTU3.TCNT (MTU6.TCNT), and switches to down-counting when MTU3.TCNT (MTU6.TCNT) matches MTU3.TGRA (MTU6.TGRA). On reaching 0000h, MTU4.TCNT (MTU7.TCNT) switches to up-counting, and the operation is repeated in this way. TCNTSA (TCNTSB) is a read-only counter. It does not need to be initialized after a reset.
In counting up by MTU3.TCNT and MTU4.TCNT (or MTU6.TCNT and MTU7.TCNT), MTU3.TCNT (or MTU6.TCNT) starts counting up when it matches TCDRA (or TCDRB) and switches to counting down when it matches MTU3.TGRA (or MTU6.TGRA). Furthermore, when MTU4.TCNT (or MTU7.TCNT) matches TDDRA (or TDDRB), TCNTSA (or TCNTSB) is set to the value in MTU3.TGRA (or MTU6.TGRA) and counting is stopped.
When MTU4.TCNT (MTU7.TCNT) matches TDDRA (TDDRB) during down-counting of MTU3.TCNT and MTU4.TCNT (MTU6.TCNT and MTU7.TCNT), TCNTSA (TCNTSB) starts up-counting, and when MTU4.TCNT (MTU7.TCNT) matches 0000h, the operation switches to down-counting. When MTU3.TCNT (MTU6.TCNT) matches TCDRA (TCDRB), TCNTSA (TCNTSB) is cleared to 0000h and stops counting.
TCNTSA (TCNTSB) is compared with the compare register and temporary register, in which the PWM duty is specified, only during the count operation.

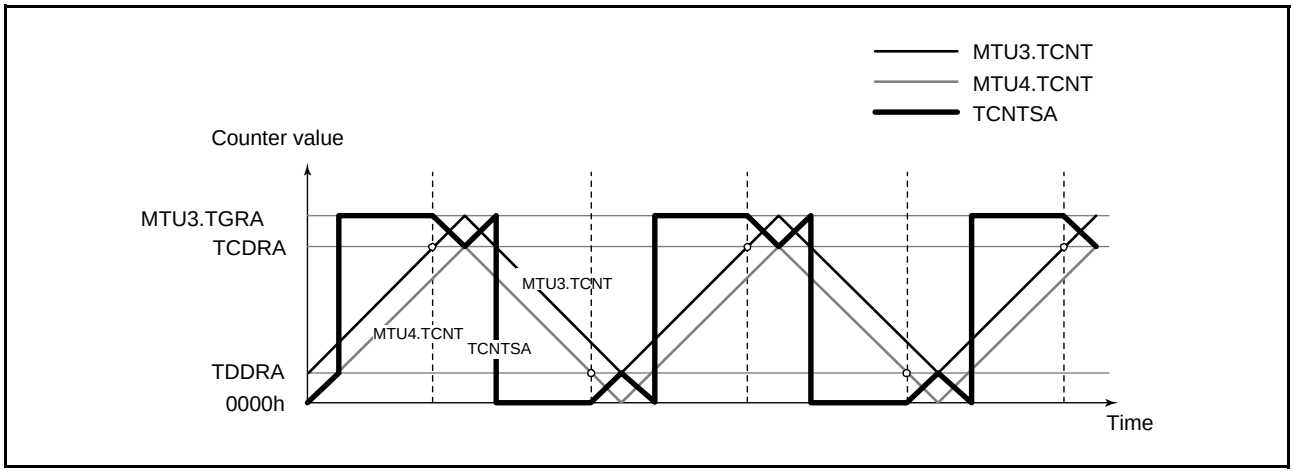


Figure 16.40 Counter Operation in Complementary PWM Mode

(b) Register Operation

In complementary PWM mode, nine registers (compare registers, buffer registers, and temporary registers) are used for each unit. Figure 16.41 shows an example of operation in complementary PWM mode (MTU3 and MTU4).
MTU3.TGRB, MTU4.TGRA, and MTU4.TGRB (MTU6.TGRB, MTU7.TGRA, and MTU7.TGRB) are constantly compared with the counters to generate PWM waveforms. When these registers match the counter, the value set in bits OLSN and OLSP in the timer output control register (TOCR1) is output.
MTU3.TGRD, MTU4.TGRC, and MTU4.TGRD (MTU6.TGRD, MTU7.TGRC, and MTU7.TGRD) are buffer registers for these compare registers.
When the double buffer function is used, MTU3.TGRE, MTU4.TGRE, and MTU4.TGRF (MTU6.TGRE, MTU7.TGRE, and MTU7.TGRF) are also used as buffer registers B. For details of double buffer operation, refer to section 16.3.8 (2) (s)Double Buffer Function in Complementary PWM Mode.
Data in a compare register can be changed by writing new data to the corresponding buffer register. The buffer registers can be read or written at any time.
The data written to a buffer register is constantly transferred to the temporary register in the Ta interval. Data is not transferred to the temporary register in the Tb interval. Data written to a buffer register in this interval is transferred to the temporary register at the end of the Tb interval.
The value transferred to a temporary register is transferred to the compare register when TCNTSA (TCNTSB) for which the Tb interval ends matches MTU3.TGRA (MTU6.TGRA) while TCNTSA (TCNTSB) is counting up, or 0000h while counting down. The timing for transfer from the temporary register to the compare register can be selected with bits MD[3:0] in the timer mode register 1 (TMDR1). Figure 16.41 shows an example in which the trough is selected for the transfer timing.
In the Tb interval in which data is not transferred to the temporary register (Tb1 in Figure 16.41), the temporary register has the same function as the compare register and is compared with the counter. In this interval, therefore, there are two compare match registers for one output phase; the compare register contains the pre-change data and the temporary register contains new data. In this interval, three counters MTU3.TCNT, MTU4.TCNT, and TCNTSA (MTU6.TCNT, MTU7.TCNT, and TCNTSB) and two registers (compare register and temporary register) are compared, and PWM output is controlled accordingly.

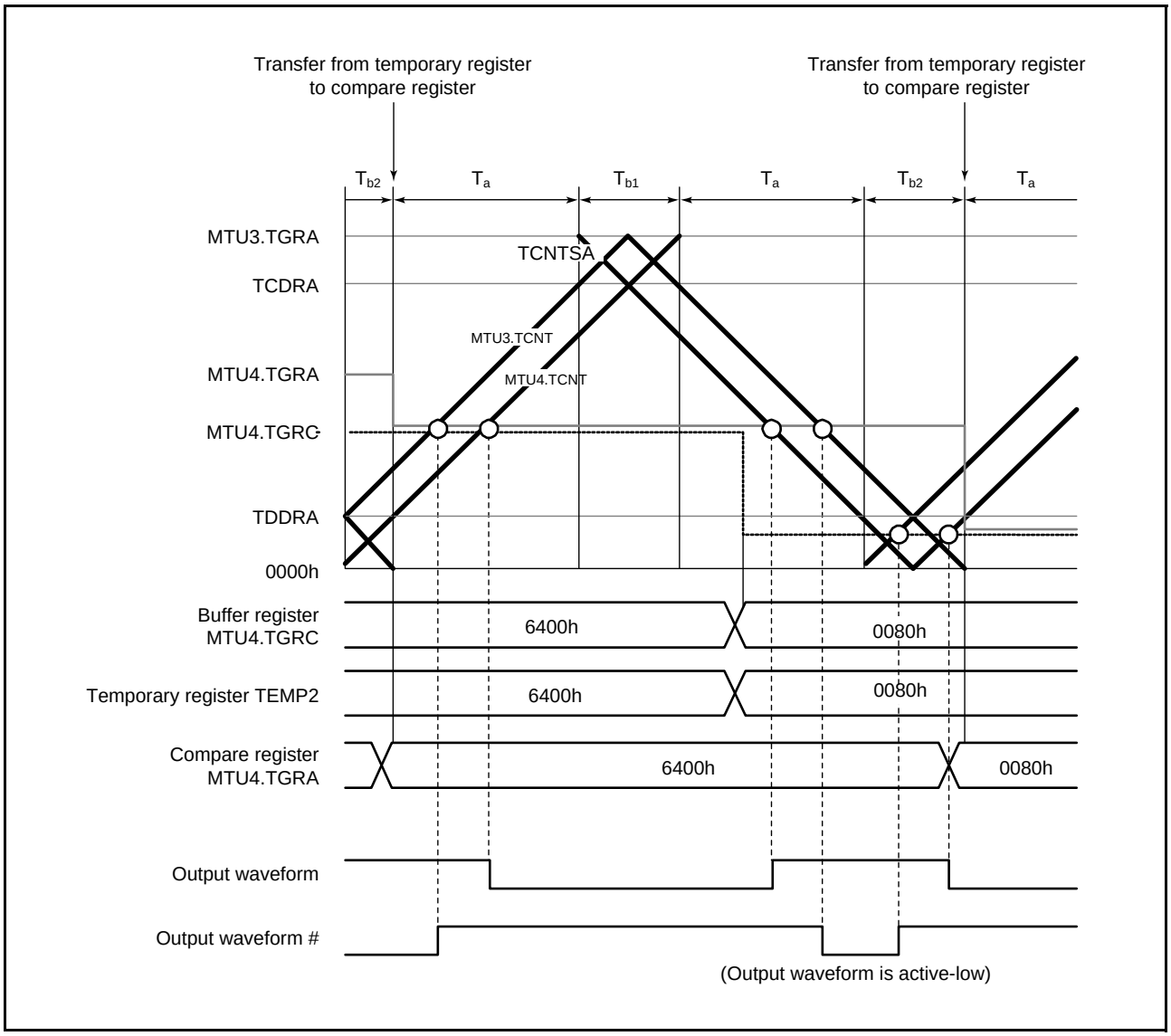


Figure 16.41 Example of Operation in Complementary PWM Mode (MTU3 and MTU4)

(c) Initial Setting

In complementary PWM mode, there are six registers that require initial setting. In addition, there is a register that specifies whether to generate dead time (it should be used only when dead time generation should be disabled).
Before setting complementary PWM mode with bits MD[3:0] in the timer mode register 1 (TMDR1), initial values should be set in the following registers.
MTU3.TGRC (MTU6.TGRC) operates as the buffer register for MTU3.TGRA (MTU6.TGRA), and should be set with 1/2 the PWM carrier cycle + dead time Td. The timer cycle buffer register (TCBRA or TCBRB) operates as the buffer register for the timer cycle data register (TCDRA or TCDRB), and should be set with 1/2 the PWM carrier cycle. Set dead time Td in the timer dead time data register (TDDRA or TDDRB).
When dead time is not needed, the TDER bit in the timer dead time enable register (TDERA or TDERB) should be cleared to 0, MTU3.TGRC and MTU3.TGRA (MTU6.TGRC and MTU6.TGRA) should be set to 1/2 the PWM carrier cycle + 1, and TDDRA (TDDRB) should be set to 1.
Set the respective initial PWM duty values in three buffer registers A (MTU3.TGRD, MTU4.TGRC, and MTU4.TGRD (MTU6.TGRD, MTU7.TGRC, and MTU7.TGRD)).
Set the respective (initial PWM duty – 1) values in three buffer registers B (MTU3.TGRE, MTU4.TGRE, and MTU4.TGRF (MTU6.TGRE, MTU7.TGRE, and MTU7.TGRF)) only when the double buffer function is used.
The values set in the five buffer registers excluding TDDRA (TDDRB) are transferred to the corresponding compare registers as soon as complementary PWM mode is set.
Set MTU4.TCNT (MTU7.TCNT) to 0000h before setting complementary PWM mode.

Table 16.72 Registers and Counters Requiring Initial Setting

Register and Counter	Setting
MTU3.TGRC MTU6.TGRC	1/2 PWM carrier cycle + dead time Td (1/2 PWM carrier cycle + 1 when dead time generation is disabled by TDERA or TDERB)
TDDRA, TDDRB	Dead time Td (1 when dead time generation is disabled by TDERA or TDERB)
TCBRA, TCBRB	1/2 PWM carrier cycle
MTU3.TGRD, MTU4.TGRC, MTU4.TGRD MTU6.TGRD, MTU7.TGRC, MTU7.TGRD	Initial PWM duty ratio value for each phase
MTU3.TGRE, MTU4.TGRE, MTU4.TGRF MTU6.TGRE, MTU7.TGRE, MTU7.TGRF	Initial PWM duty ratio – 1 value for each phase (only when double buffer function is used)
MTU4.TCNT MTU7.TCNT	0000h

Note 1. The value set in MTU3.TGRC (MTU6.TGRC) should be the sum of 1/2 the PWM carrier cycle set in TCBRA (TCBRB) and dead time Td set in TDDRA (TDDRB). When dead time generation is disabled by TDERA (TDERB), TGRC should be set to 1/2 the PWM carrier cycle + 1.

(d) PWM Output Level Setting

In complementary PWM mode, the PWM pulse output level is set with bits OLSN and OLSP in timer output control register 1 (TOCR1A or TOCR1B) or bits OLS1P to OLS3P and OLS1N to OLS3N in timer output control register 2 (TOCR2A or TOCR2B).
The output level can be set for each of the three positive phases and three negative phases of 6-phase output.
Complementary PWM mode should be cleared before setting or changing output levels.

(e) Dead Time Setting

In complementary PWM mode, PWM pulses are output with a non-overlapping relationship between the positive and negative phases. This non-overlap time is called the dead time.
The non-overlap time is set in the timer dead time data register (TDDRA or TDDRB). The value set in TDDRA (TDDRB) is used as the MTU3.TCNT (MTU6.TCNT) counter start value and creates a non-overlapping interval between MTU3.TCNT (MTU6.TCNT) and MTU4.TCNT (MTU7.TCNT). Complementary PWM mode should be cleared before changing the contents of TDDRA (TDDRB).

(f) Dead Time Suppressing

Dead time generation is suppressed by clearing the TDER bit in the timer dead time enable register (TDERA or TDERB) to 0. TDERA (TDERB) can be cleared to 0 only when 0 is written to it after reading TDER = 1.
MTU3.TGRA and MTU4.TGRC (MTU6.TGRA and MTU7.TGRC) should be set to 1/2 PWM carrier cycle + 1 and the timer dead time data register (TDDRA or TDDRB) should be set to 1.
By the above settings, PWM waveforms without dead time can be obtained. Figure 16.42 shows an example of operation without dead time (MTU3 and MTU4).

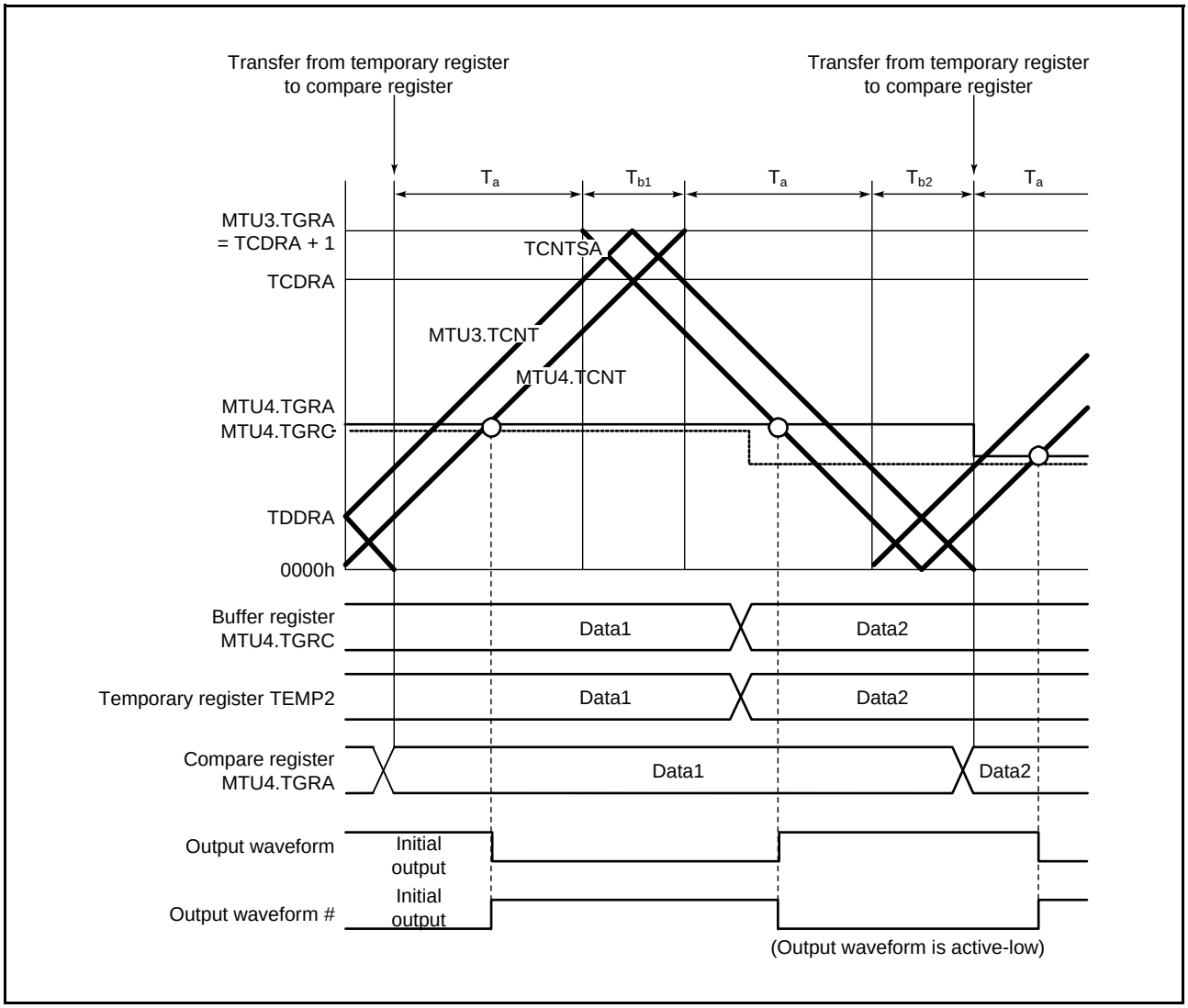


Figure 16.42 Example of Operation without Dead Time (MTU3 and MTU4)

(g) PWM Cycle Setting

In complementary PWM mode, the PWM pulse cycle is set in two registers—MTU3.TGRA (MTU6.TGRA), in which the MTU3.TCNT (MTU6.TCNT) upper limit value is set, and TCDRA (TCDRB), in which the MTU4.TCNT (MTU7.TCNT) upper limit value is set. The settings should be made so as to achieve the following relationship between these two registers:

With dead time: MTU3.TGRA (MTU6.TGRA) setting = TCDRA (TCDRB) setting + TDDRA (TDDRB) setting
Without dead time: MTU3.TGRA (MTU6.TGRA) setting = TCDRA (TCDRB) setting + 1

The MTU3.TGRA and TCDRA (MTU6.TGRA and TCDRB) settings are made by setting values in buffer registers MTU3.TGRC and TCBRA (MTU6.TGRC and TCBRB). The values set in MTU3.TGRC and TCBRA (MTU6.TGRC and TCBRB) are transferred simultaneously to MTU3.TGRA and TCDRA (MTU6.TGRA and TCDRB) with the transfer timing selected with bits MD[3:0] in the timer mode register 1 (TMDR1).
The new PWM cycle is reflected from the next cycle when data is updated at the crest, or from the current cycle when updated in the trough. Figure 16.43 illustrates the operation when the PWM cycle is updated at the crest.
See the following section, (h)Register Data Updating, for the method of updating the data in each buffer register.

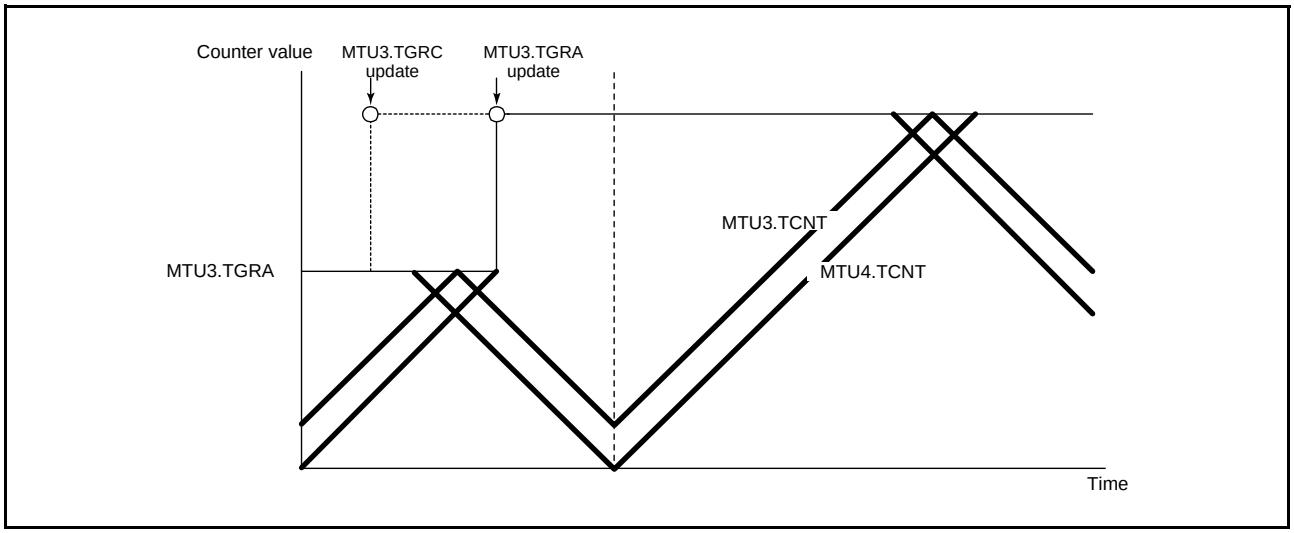


Figure 16.43 Example of PWM Cycle Updating (MTU3 and MTU4)

(h) Register Data Updating

In complementary PWM mode, the buffer register is used to update the data in a compare register. The update data can be written to the buffer register at any time. There are five registers (PWM duty and carrier cycle registers) that have buffer registers and can be updated during operation.

There is a temporary register between each of these registers and its buffer register. While subcounter TCNTSA (TCNTSB) is not counting, if buffer register data is updated, the temporary register value also changes. Data is not transferred from buffer registers to temporary registers while TCNTSA (TCNTSB) is counting; in this case, the value written to a buffer register is transferred after TCNTSA (TCNTSB) halts.

The temporary register value is transferred to the compare register at the data update timing set with bits MD[3:0] in the timer mode register 1 (TMDR1). Figure 16.44 shows an example of data updating in complementary PWM mode (MTU3 and MTU4). This example shows the mode in which data is updated at both the counter crest and trough.

When updating buffer register data, be sure to write to MTU4.TGRD (MTU7.TGRD) at the end of the update. Data is transferred from buffer registers to the temporary registers simultaneously for all five registers after the write to MTU4.TGRD (MTU7.TGRD).

Even when not updating all five registers or when not updating the MTU4.TGRD (MTU7.TGRD) data, be sure to write to MTU4.TGRD (MTU7.TGRD) after writing data to the registers to be updated. In this case, the data written to MTU4.TGRD (MTU7.TGRD) should be the same as the data prior to the write operation.

See section 16.3.8 (2) (s)Double Buffer Function in Complementary PWM Mode, for data updating when the double buffer function is used.

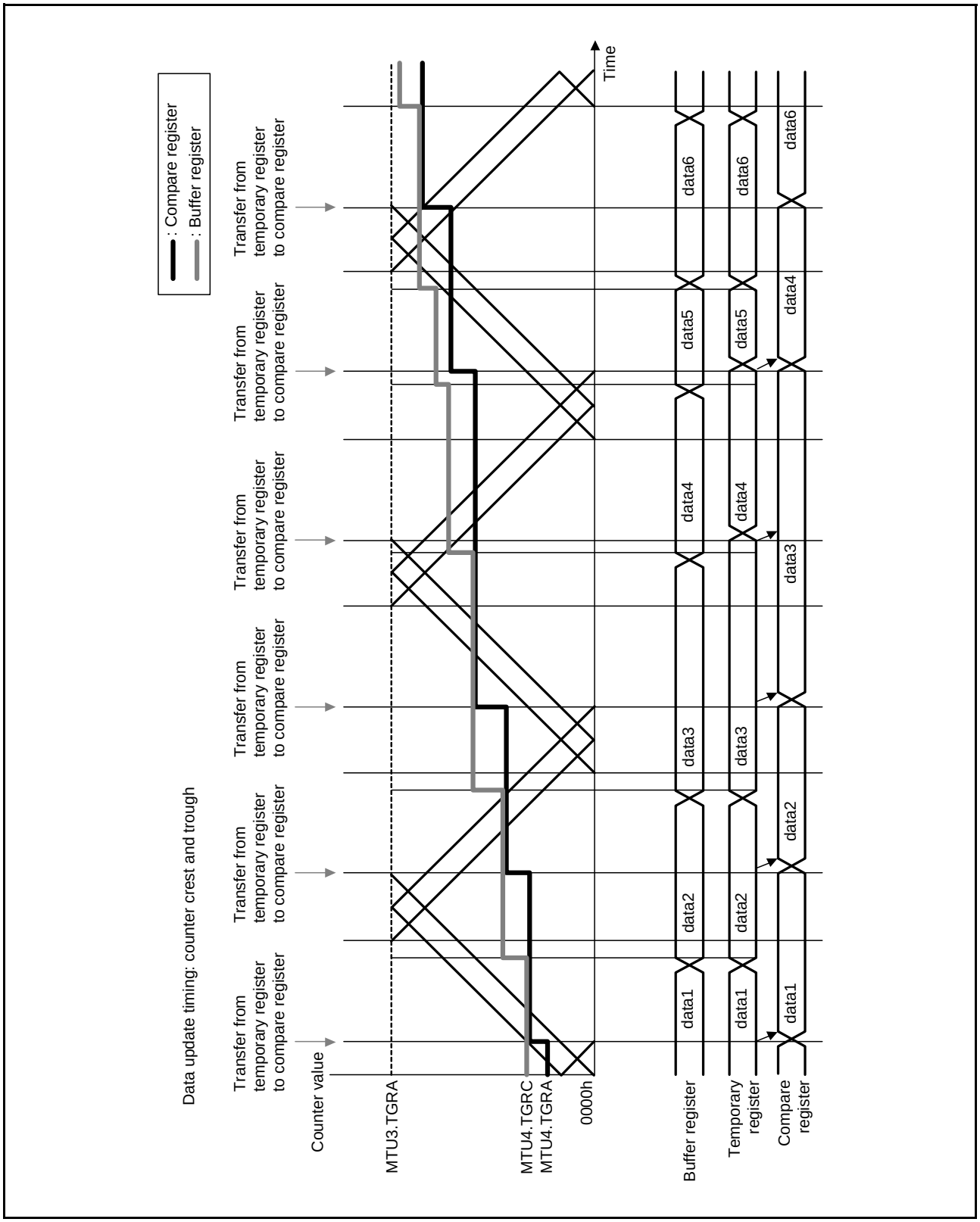


Figure 16.44 Example of Data Updating in Complementary PWM Mode (MTU3 and MTU4)

(i) Initial Output in Complementary PWM Mode

In complementary PWM mode, the initial output is determined by the setting of bits OLSN and OLSP in timer output control register 1 (TOCR1A or TOCR1B) or bits OLS1N to OLS3N and OLS1P to OLS3P in timer output control register 2 (TOCR2A or TOCR2B).

This initial output is the non-active level of the PWM pulse and continues from when complementary PWM mode is set with the timer mode register 1 (TMDR1) until MTU4.TCNT (MTU7.TCNT) exceeds the value set in the dead time register (TDDRA or TDDRB). Figure 16.45 shows an example of the initial output in complementary PWM mode. An example of the waveform when the initial PWM duty ratio value is smaller than the TDDRA (TDDRB) value is shown in Figure 16.46.

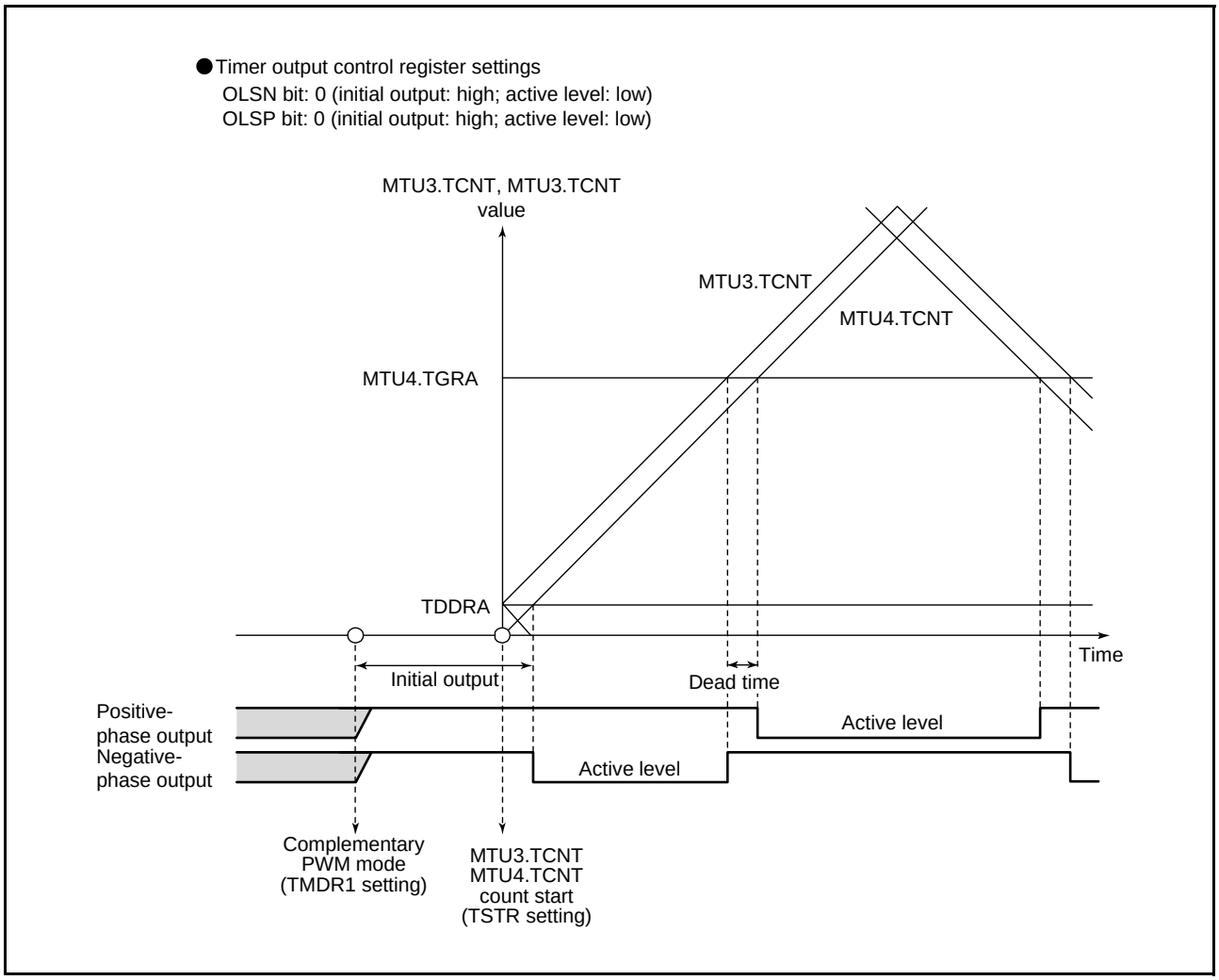


Figure 16.45 Example of Initial Output in Complementary PWM Mode (MTU3 and MTU4) (1))

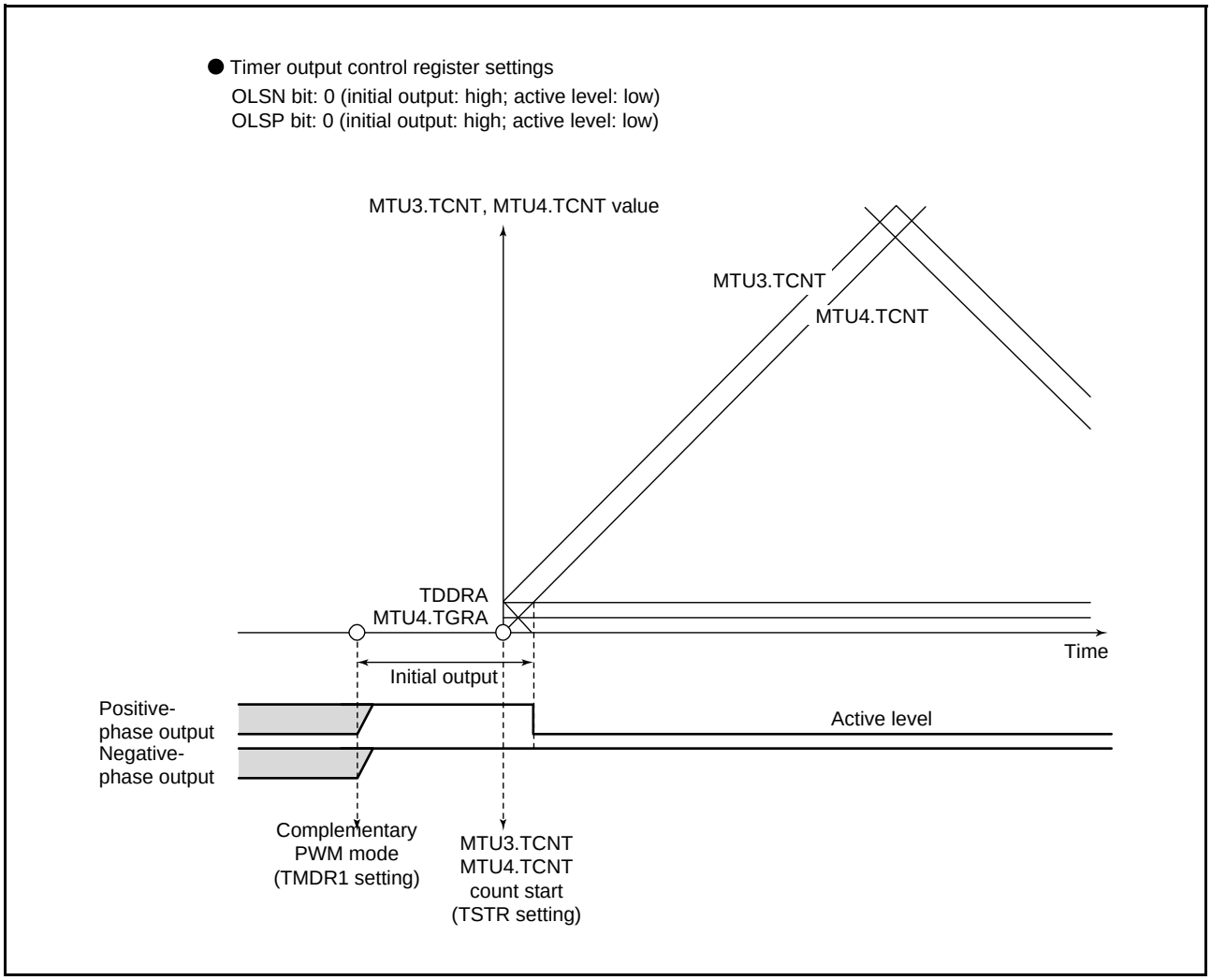


Figure 16.46 Example of Initial Output in Complementary PWM Mode (MTU3 and MTU4) (2)

(j) Method for Generating PWM Output in Complementary PWM Mode

In complementary PWM mode, three phases of PWM waveforms are output with a non-overlap time between the positive and negative phases. This non-overlap time is called the dead time.

A PWM waveform is generated by output of the level selected in the timer output control register in the event of a compare match between a counter and a compare register. While TCNTSA (TCNTSB) is counting, the compare register and temporary register values are simultaneously compared to create consecutive PWM pulses from 0 to 100%. The relative timing of turn-on and turn-off compare match occurrence may vary, but the compare match that turns off each phase takes precedence to secure the dead time and ensure that the positive-phase and negative-phase turn-on times do not overlap. Figure 16.47 to Figure 16.49 show examples of waveform generation in complementary PWM mode.

The positive-phase and negative-phase turn-off timing is generated by a compare match with the counter value indicated in solid lines in the figure, and the turn-on timing by a compare match with the counter indicated in dotted lines, which operates with a delay of the dead time behind the solid-line counter. In the T1 period, compare match a that turns off the negative phase has the highest priority, and compare matches before a are ignored. In the T2 period, compare match c that turns off the positive phase has the highest priority, and compare matches before c are ignored.

In most cases, compare matches occur in the order a → b → c → d (or c → d → a' → b') as shown in Figure 16.47.

If compare matches deviate from the a → b → c → d order, since the time for which the negative phase is off is shorter than twice the dead time, the positive phase is not turned on. If compare matches deviate from the c → d → a' → b' order, since the time for which the positive phase is off is shorter than twice the dead time, the negative phase is not turned on.

As shown in Figure 16.48, if compare match c follows compare match a before compare match b, compare match b is ignored and the negative phase is turned on by compare match d. This is because turning off the positive phase has priority due to the occurrence of compare match c (positive-phase off timing) before compare match b (positive-phase on timing) (consequently, the waveform does not change because the positive phase goes from off to off).

Similarly, in the example in Figure 16.49, compare match a' with new data in the temporary register occurs before compare match c, but until compare match c, which turns off the positive phase, other compare matches are ignored. As a result, the negative phase is not turned on.

Thus, in complementary PWM mode, compare matches at turn-off timings take precedence, and turn-on timing compare matches that occur before a turn-off timing compare match are ignored.

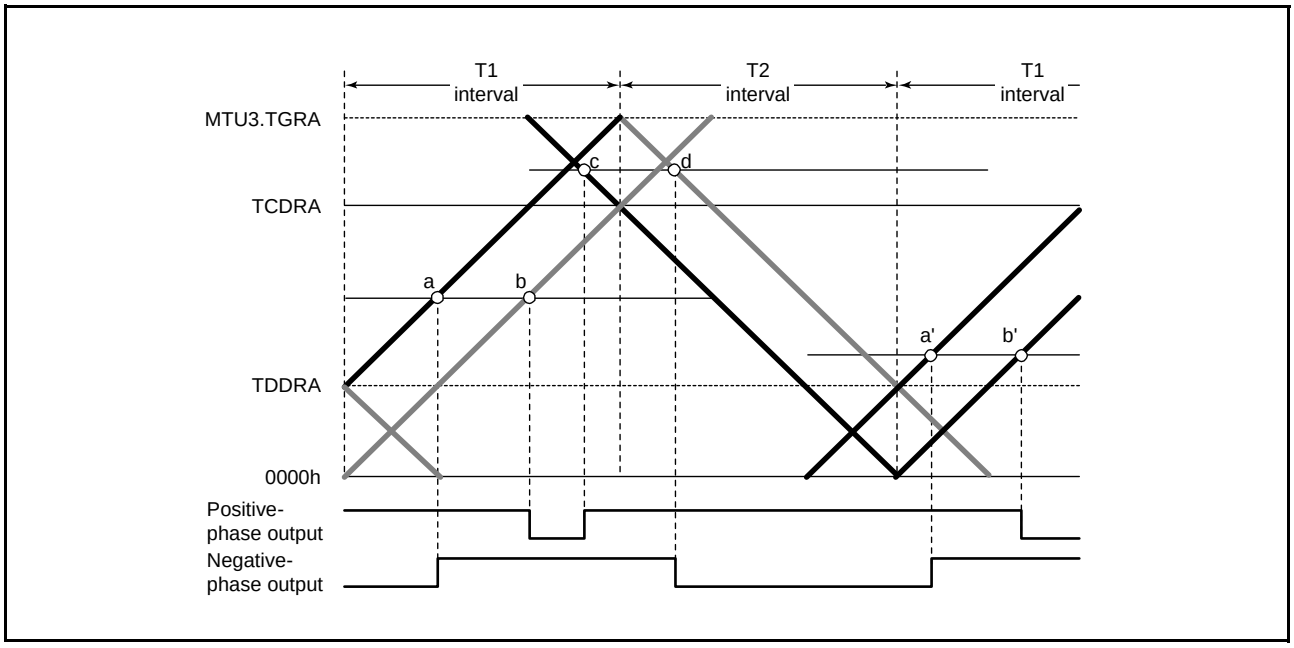


Figure 16.47 Example of Waveform Output in Complementary PWM Mode (MTU3 and MTU4) (1)

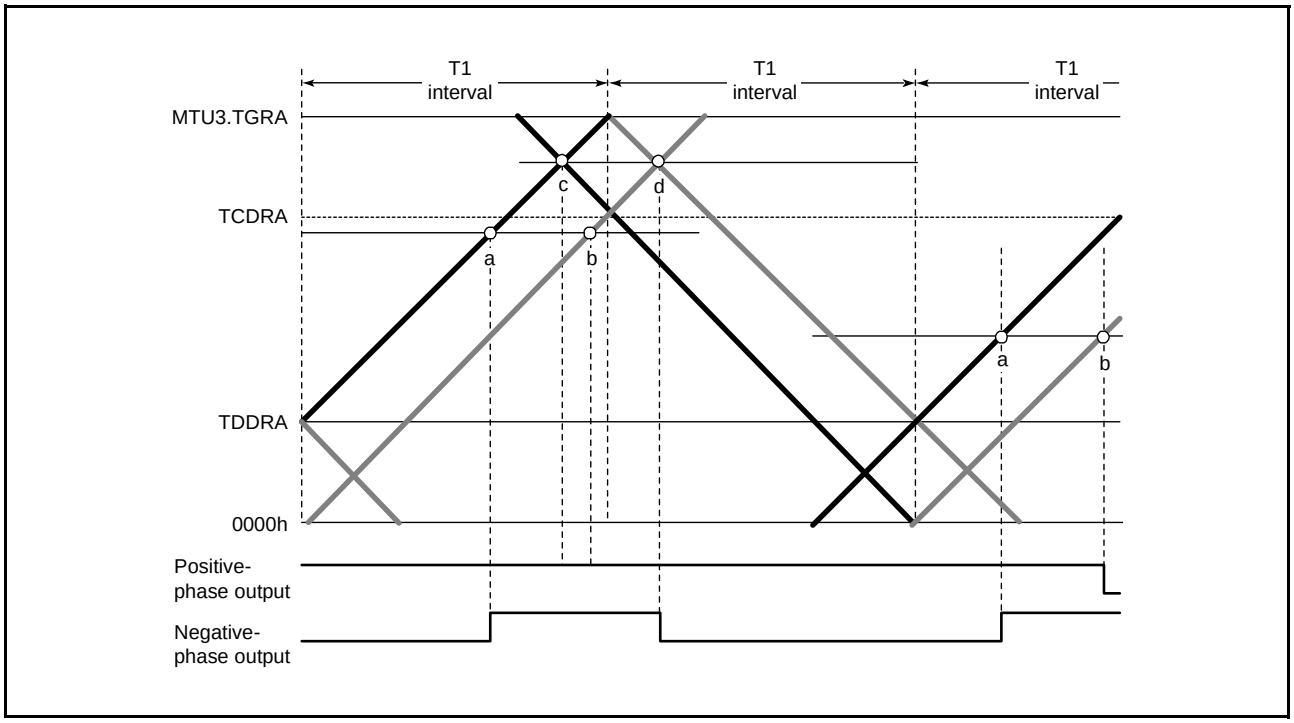


Figure 16.48 Example of Waveform Output in Complementary PWM Mode (MTU3 and MTU4) (2)

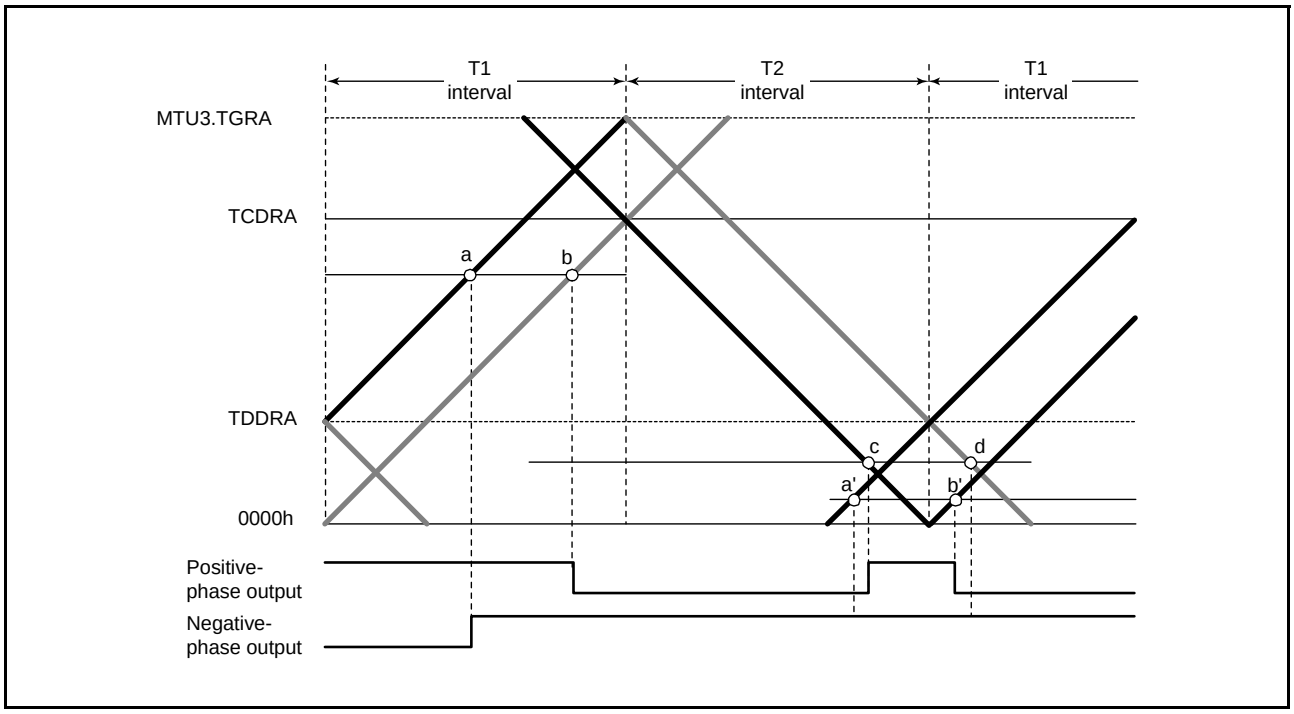


Figure 16.49 Example of Waveform Output in Complementary PWM Mode (MTU3 and MTU4) (3)

(k) 0% and 100% duty ratio Output in Complementary PWM Mode

In complementary PWM mode, 0% and 100% duty PWM waveforms can be output as required. Figure 16.50 to Figure 16.54 show output examples.

A 100% duty waveform is output when the compare register value is set to 0000h. The waveform in this case has a positive phase with a 100% on-state. A 0% duty waveform is output when the compare register value is set to the same value as MTU3.TGRA (MTU6.TGRA). The waveform in this case has a positive phase with a 100% off-state.

On and off compare matches occur simultaneously, but if a turn-on compare match and turn-off compare match for the same phase occur simultaneously, both compare matches are ignored and the waveform does not change.

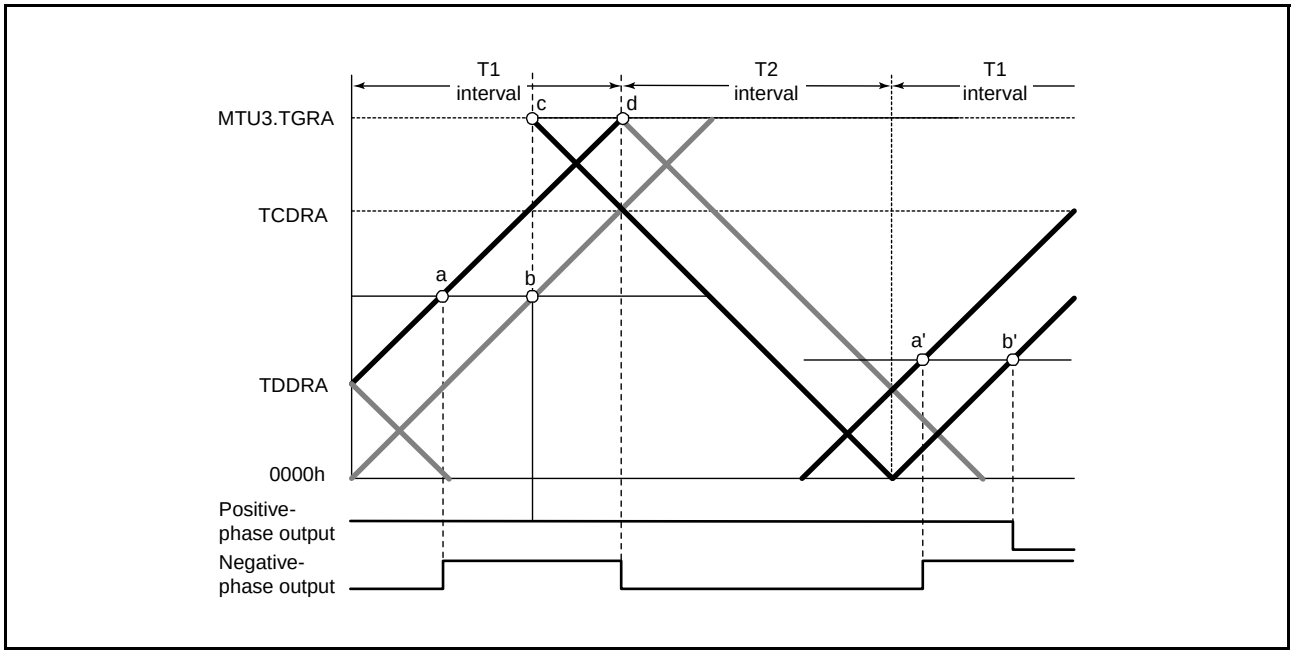


Figure 16.50 Example of 0% and 100% Waveform Output in Complementary PWM Mode (MTU3 and MTU4) (1)

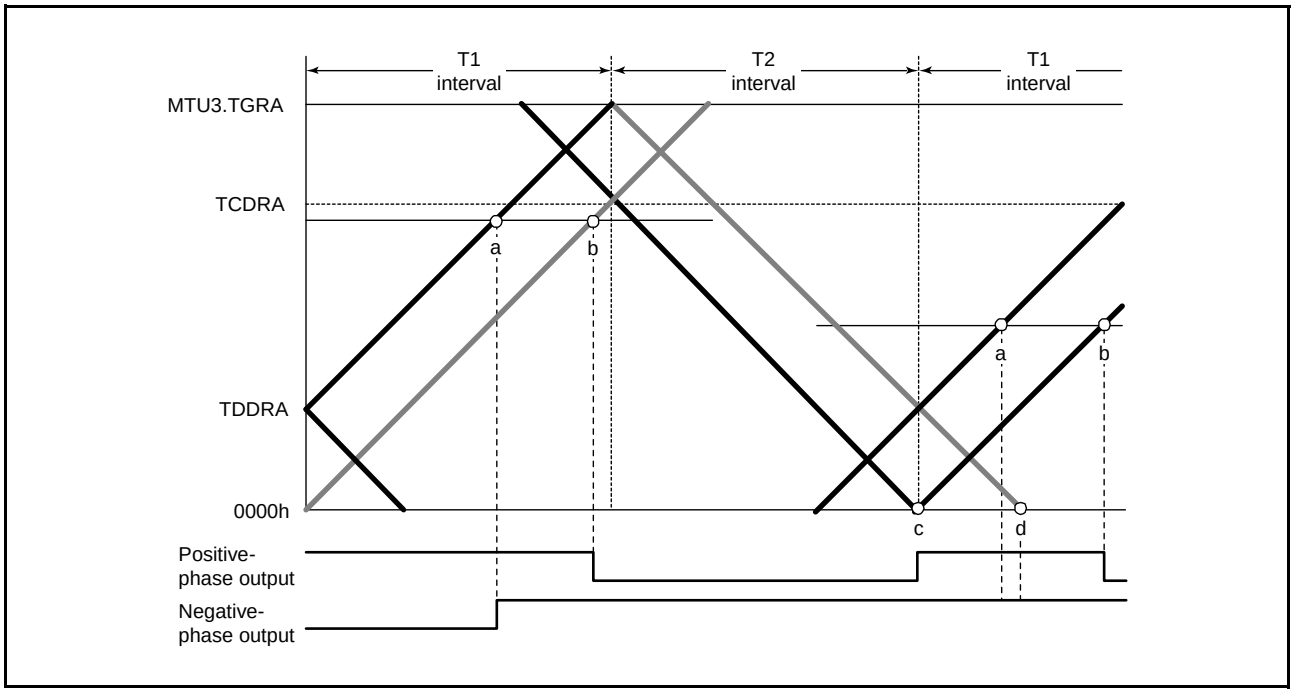


Figure 16.51 Example of 0% and 100% Waveform Output in Complementary PWM Mode (MTU3 and MTU4) (2)

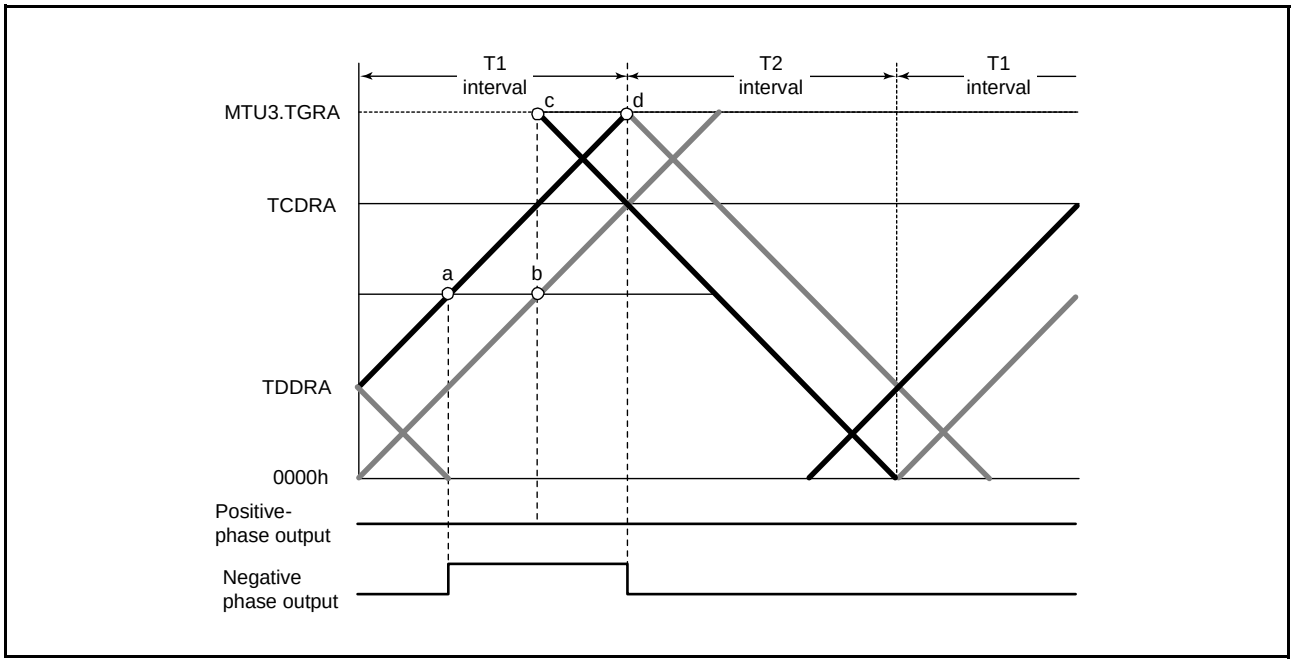


Figure 16.52 Example of 0% and 100% Waveform Output in Complementary PWM Mode (MTU3 and MTU4) (3)

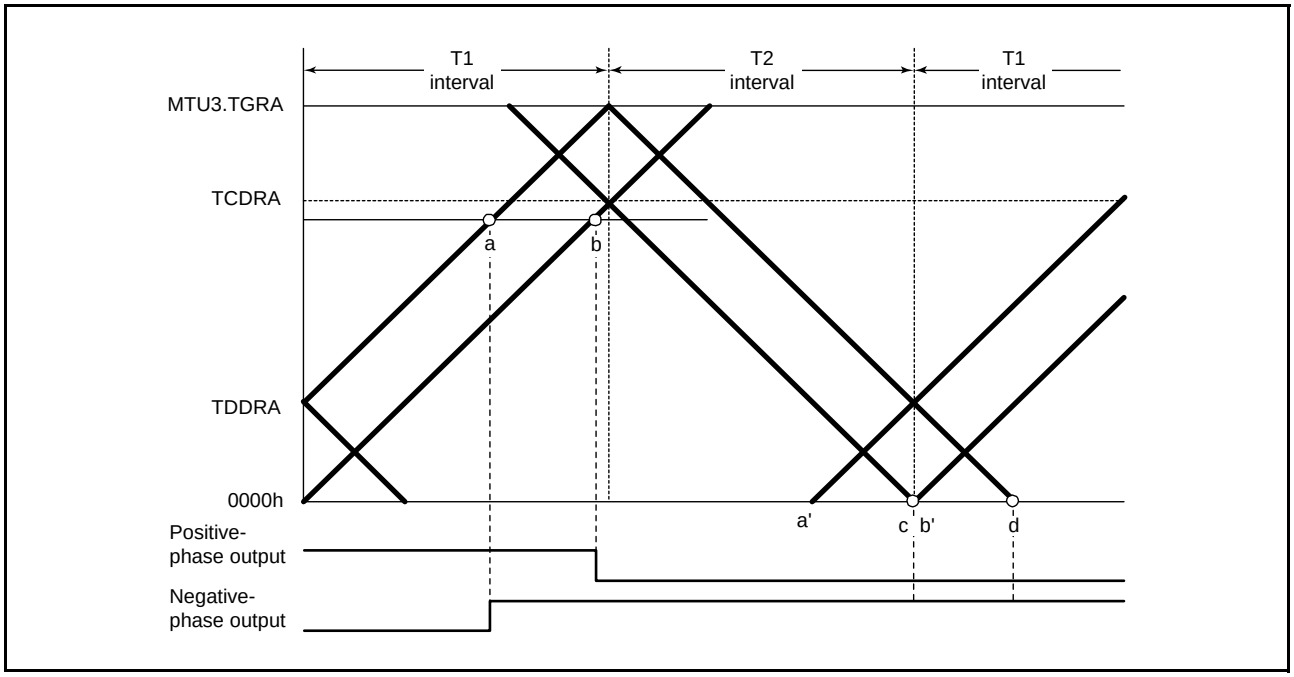


Figure 16.53 Example of 0% and 100% Waveform Output in Complementary PWM Mode (MTU3 and MTU4) (4)

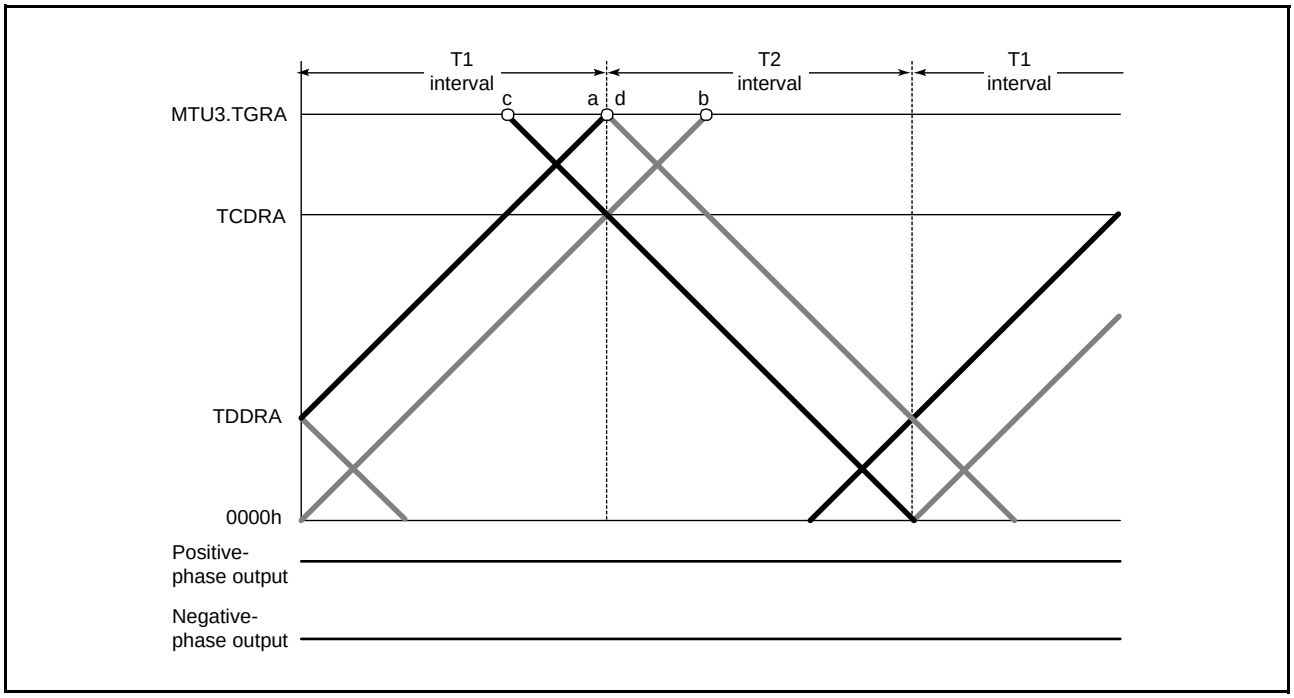


Figure 16.54 Example of 0% and 100% Waveform Output in Complementary PWM Mode (MTU3 and MTU4) (5)

(l) Toggle Output Synchronized with PWM Cycle

In complementary PWM mode, toggle output in synchronization with the PWM carrier cycle can be generated by setting the PSYE bit to 1 in the timer output control register 1 (TOCR1A or TOCR1B). An example of a toggle output waveform is shown in Figure 16.55.

This output is toggled by a compare match between MTU3.TCNT and MTU3.TGRA (MTU6.TCNT and MTU6.TGRA) and a compare match between MTU4.TCNT (MTU7.TCNT) and 0000h.

The MTIOC3A (MTIOC6A) pin is assigned for this toggle output. The initial output is High.

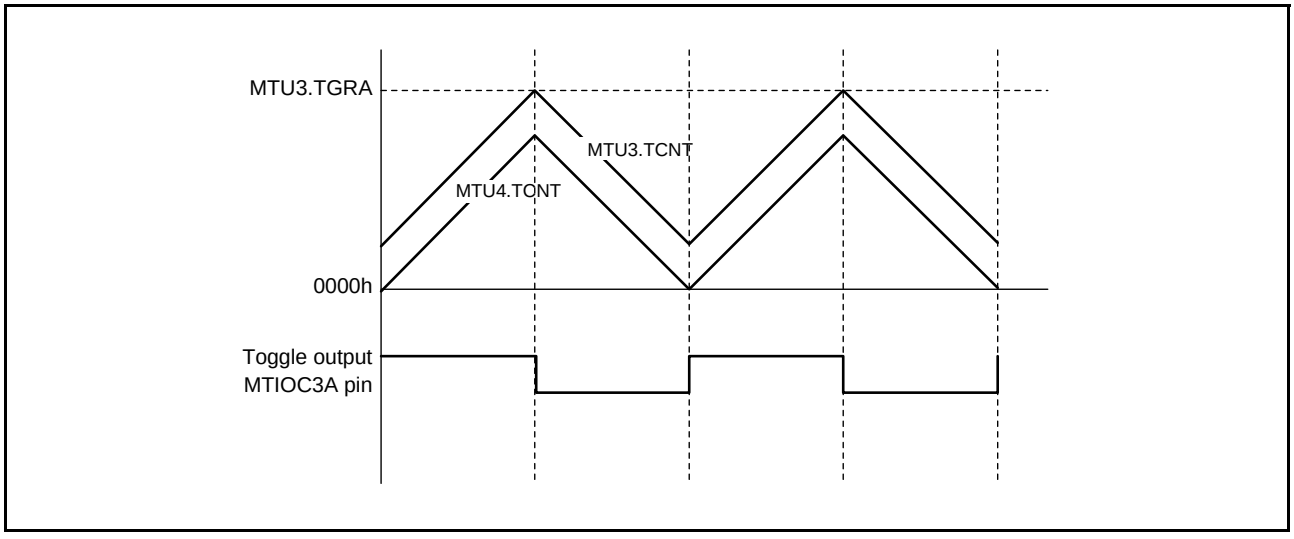


Figure 16.55 Example of Toggle Output Waveform Synchronized with PWM Output (MTU3 and MTU4)

(m) Counter Clearing by Another Channel

In complementary PWM mode, MTU3.TCNT, MTU4.TCNT, and TCNTSA (MTU6.TCNT, MTU7.TCNT, and TCNTSB) can be cleared by another channel when a mode for synchronization with another channel is specified through the timer synchronous register (TSYRA or TSYRB)) and synchronous clearing is selected with bits CCLR[2:0] in the timer control register (TCR).

Figure 16.56 illustrates an example of this operation.

Use of this function enables a counter to be cleared and restarted through an external signal.

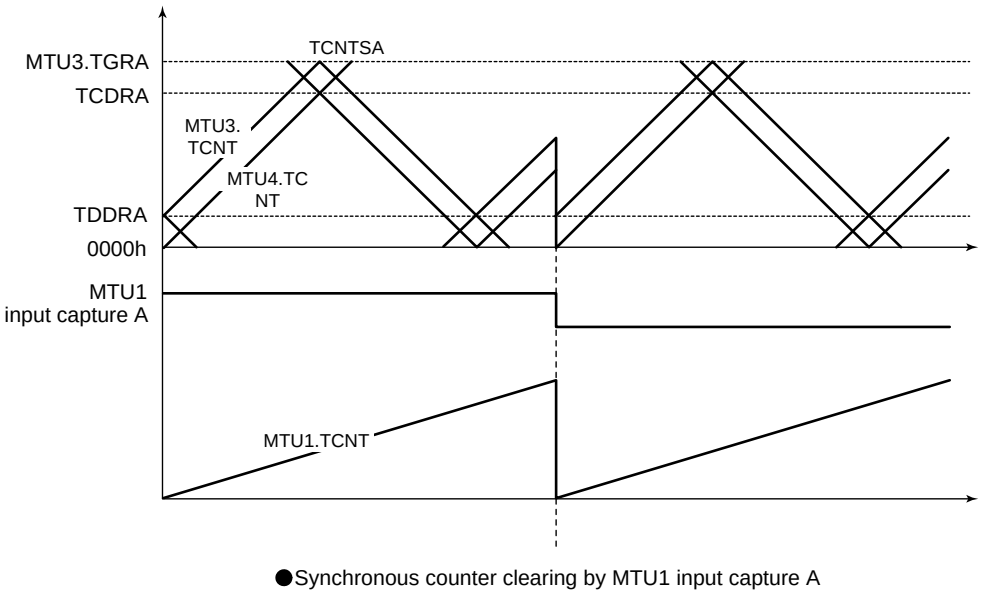


Figure 16.56 Counter Clearing Synchronized with Another Channel (MTU3 and MTU4)

(n) Output Waveform Control at Synchronous Counter Clearing in Complementary PWM Mode

Setting the WRE bit in TWCRA (TWCRB) to 1 suppresses initial output when synchronous counter clearing occurs in the Tb interval at the trough in complementary PWM mode and controls abrupt change in duty cycle at synchronous counter clearing.

Initial output suppression through the WRE bit = 1 is applicable only when synchronous clearing occurs in the Tb interval at the trough as indicated by (10) or (11) in Figure 16.57. When synchronous clearing occurs outside that interval, the initial value specified by the OLS bits in TOCR1A (TOCR1B) is output. Even in the Tb interval at the trough, if synchronous clearing occurs in the initial value output period (indicated by (1) in Figure 16.57) immediately after the counters start operation, initial value output is not suppressed.

This function can be used in both channel combinations of MTU3 and MTU4, and MTU6 and MTU7. In MTU3 and MTU4, synchronous clearing generated in MTU0 and MTU2 can cause counter clearing; in MTU6 and MTU7, flag setting (compare match or input capture) in MTU0 and MTU2 can cause counter clearing.

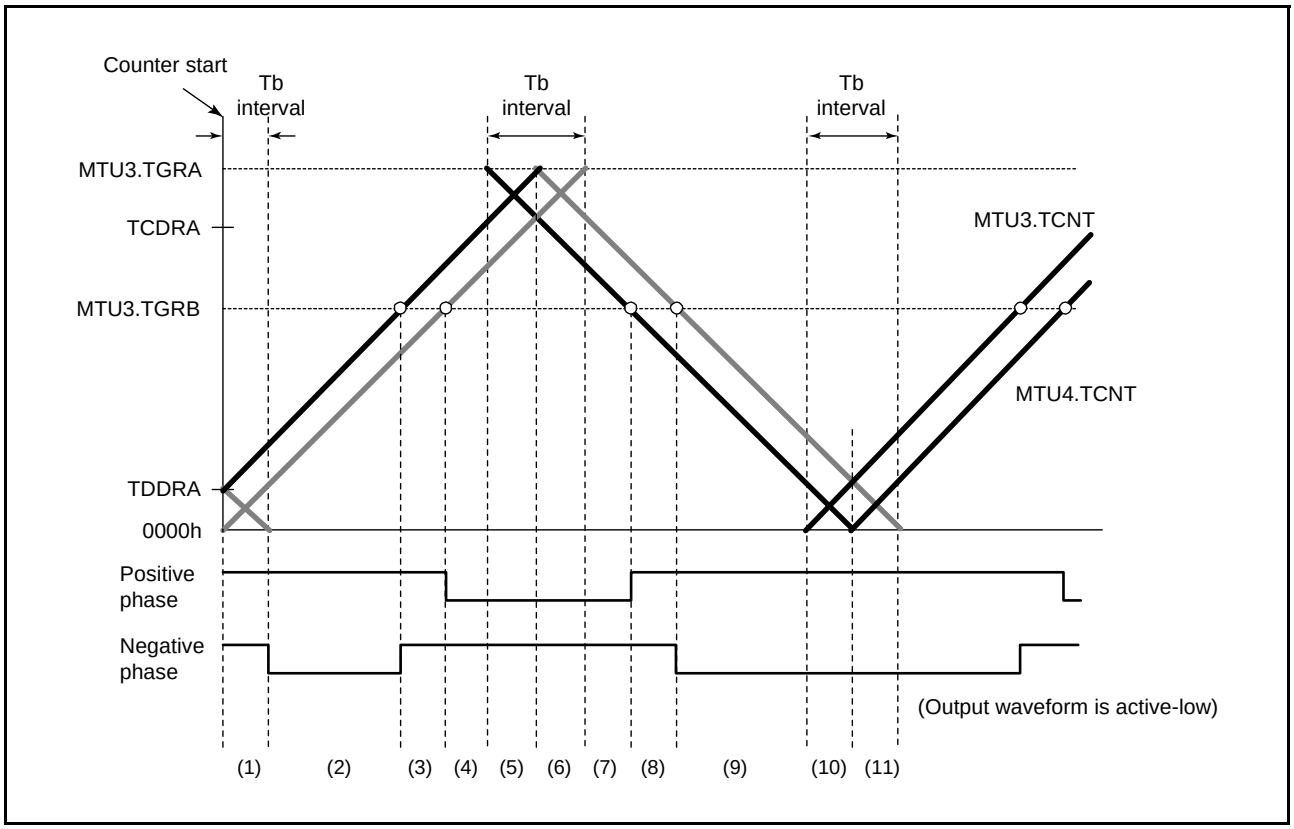


Figure 16.57 Timing for Synchronous Counter Clearing (MTU3 and MTU4)

- Example of Procedure for Setting Output Waveform Control at Synchronous Counter Clearing in Complementary PWM Mode.

An example of the procedure for setting output waveform control at synchronous counter clearing in complementary PWM mode is shown in Figure 16.58.

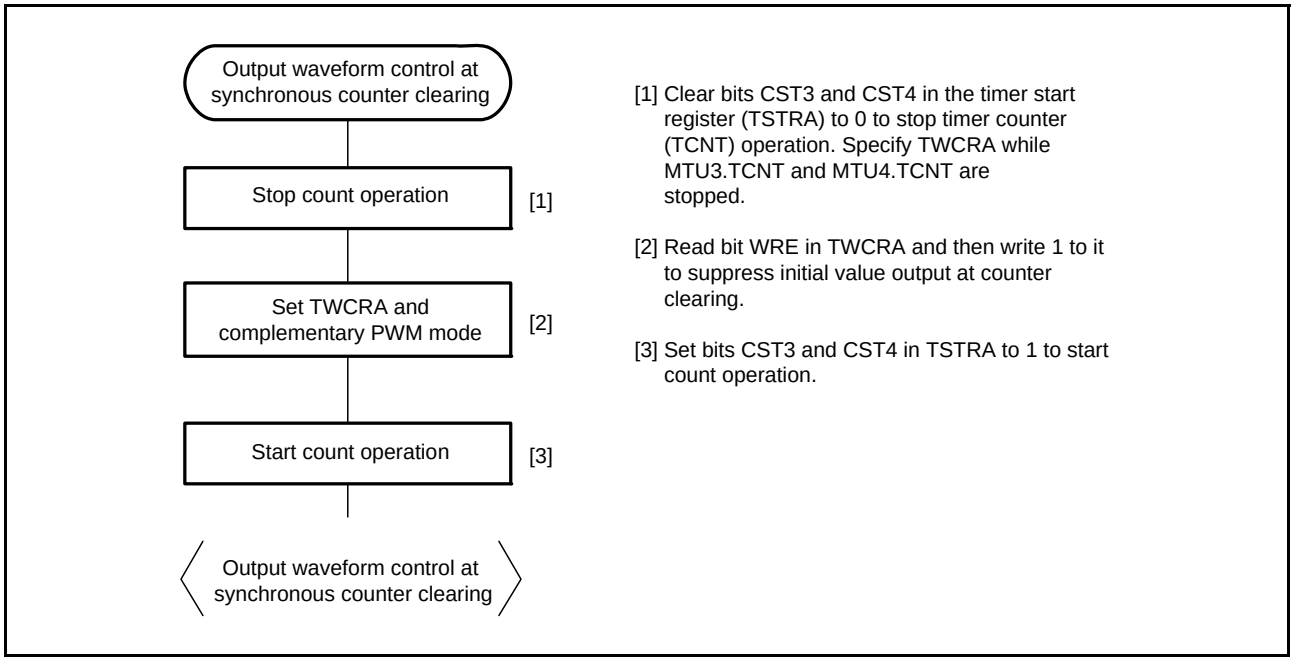


Figure 16.58 Example of Procedure for Setting Output Waveform Control at Synchronous Counter Clearing in Complementary PWM Mode (MTU3 and MTU4)

- Examples of Output Waveform Control at Synchronous Counter Clearing in Complementary PWM Mode

Figure 16.59 to Figure 16.62 show examples of output waveform control in which MTU3 and MTU4 operate in complementary PWM mode and synchronous counter clearing is generated while the WRE bit in TWCRA is set to 1. In the examples shown in Figure 16.59 to Figure 16.62, synchronous counter clearing occurs at timing (3), (6), (8), and (11) shown in Figure 16.57, respectively.

In MTU6 and MTU7, these examples are equivalent to the cases when MTU6 and MTU7 operate in complementary PWM mode and synchronous counter clearing is generated while the SCC bit is cleared to 0 and the WRE bit is set to 1 in TWCRB.

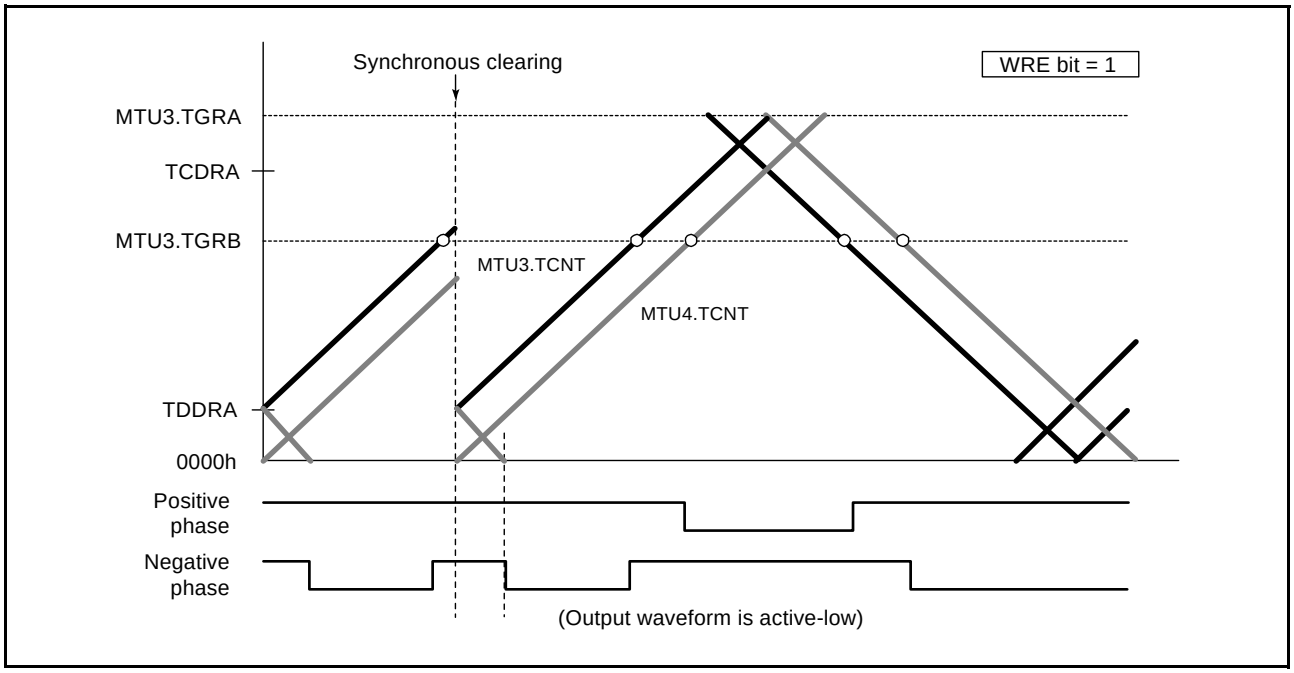


Figure 16.59 Example of Synchronous Clearing in Dead Time during Up-Counting (Timing (3) in Figure 16.57; Bit WRE of TWCRA or TWCRB is 1)

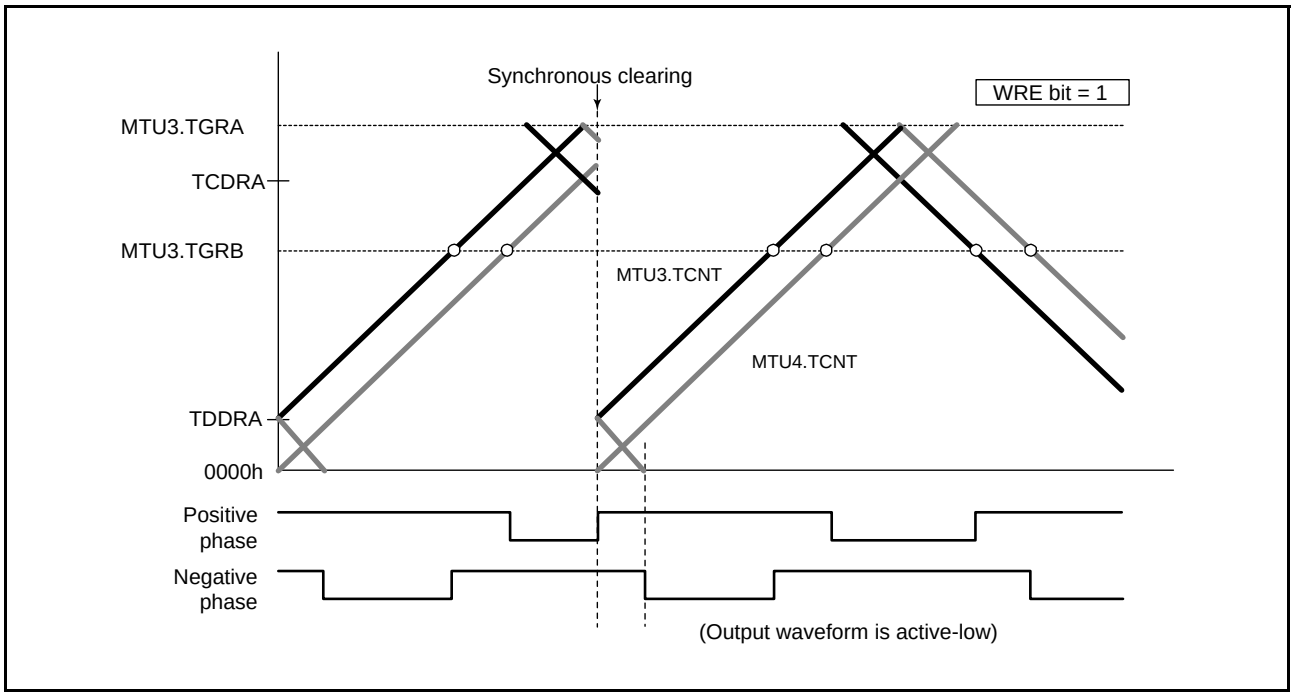


Figure 16.60 Example of Synchronous Clearing in Interval Tb at Crest (Timing (6) in Figure 16.57; Bit WRE of TWCRA or TWCRB is 1)

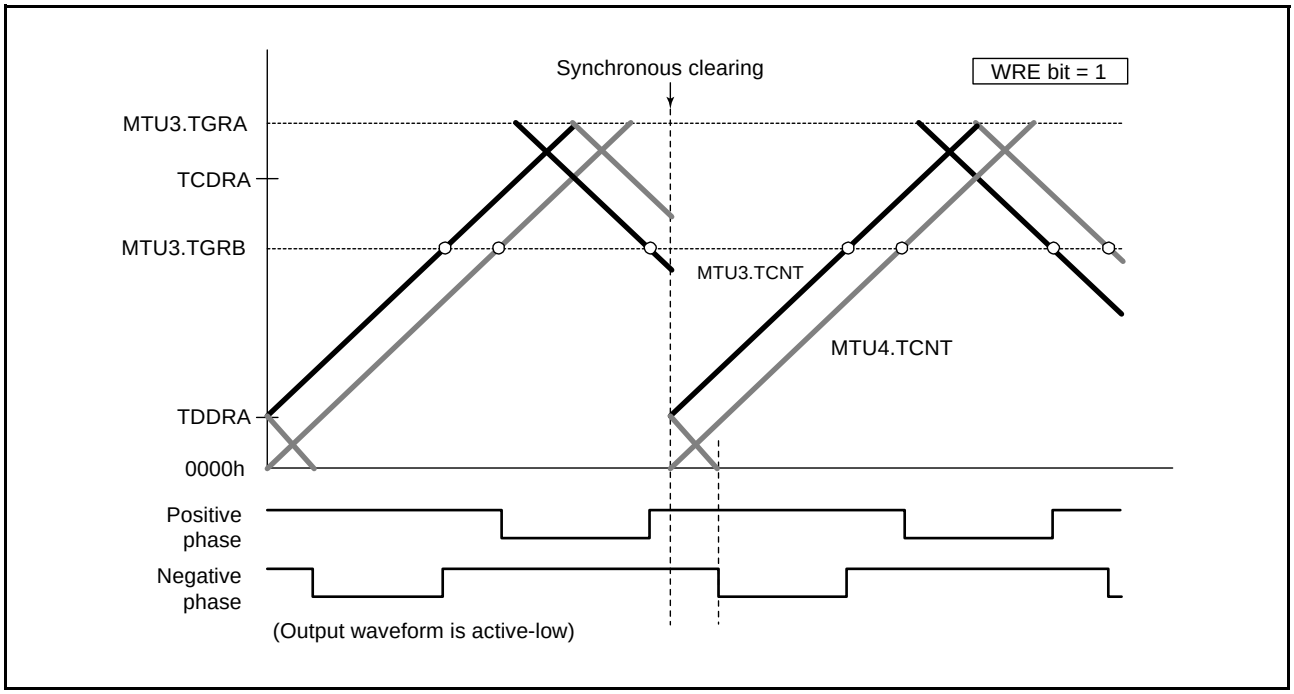


Figure 16.61 Example of Synchronous Clearing in Dead Time during Down-Counting (Timing (8) in Figure 16.57; Bit WRE of TWCRA or TWCRB is 1)

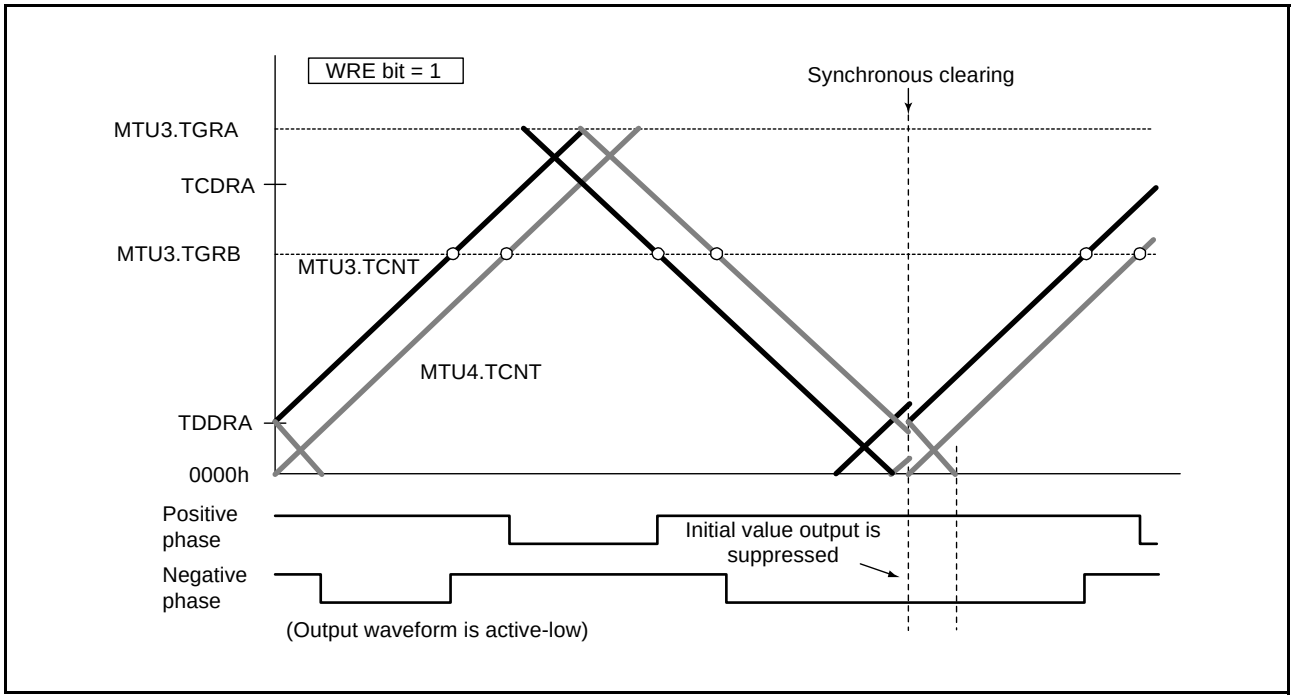


Figure 16.62 Example of Synchronous Clearing in Interval Tb at Trough (Timing (11) in Figure 16.57; Bit WRE of TWCRA or TWCRB is 1)

(o) Suppressing Synchronous Counter Clearing for MTU0 to MTU2, and MTU6 and MTU7

In MTU6 and MTU7, setting the SCC bit in TWCRB to 1 suppresses synchronous counter clearing caused by MTU0 to 2.

Synchronous counter clearing is suppressed only within the interval shown in Figure 16.63. When using this function, MTU6 and MTU7 should be set to complementary PWM mode.

For details of synchronous clearing caused by MTU0 and MTU2, refer to section 16.3.10 (2)Clearing Counters of MTU6 and MTU7 by Flag Setting Sources (Synchronous Counter Clearing for MTU6 and MTU7).

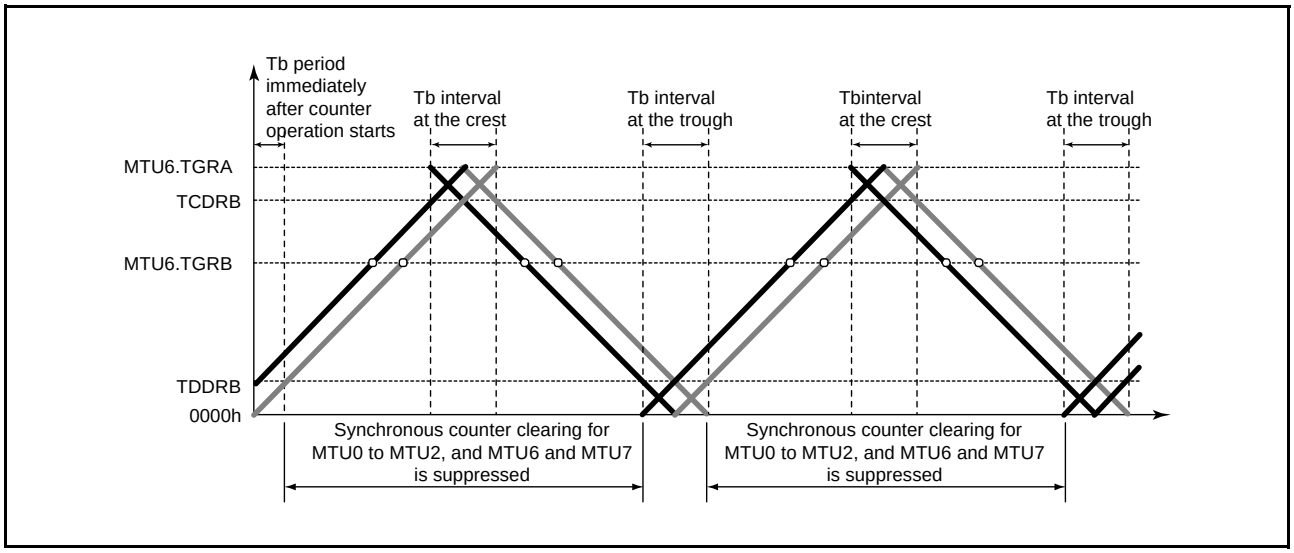


Figure 16.63 Synchronous Clearing-Suppressed Interval Specified by SCC Bit in TWCRB for MTU0 to MTU2, and MTU6 and MTU7

- Example of Procedure for Suppressing Synchronous Counter Clearing for MTU0 to MTU2, and MTU6 and MTU7

An example of the procedure for suppressing synchronous counter clearing for MTU0 to MTU2, and MTU6 and MTU7 is shown in Figure 16.64.

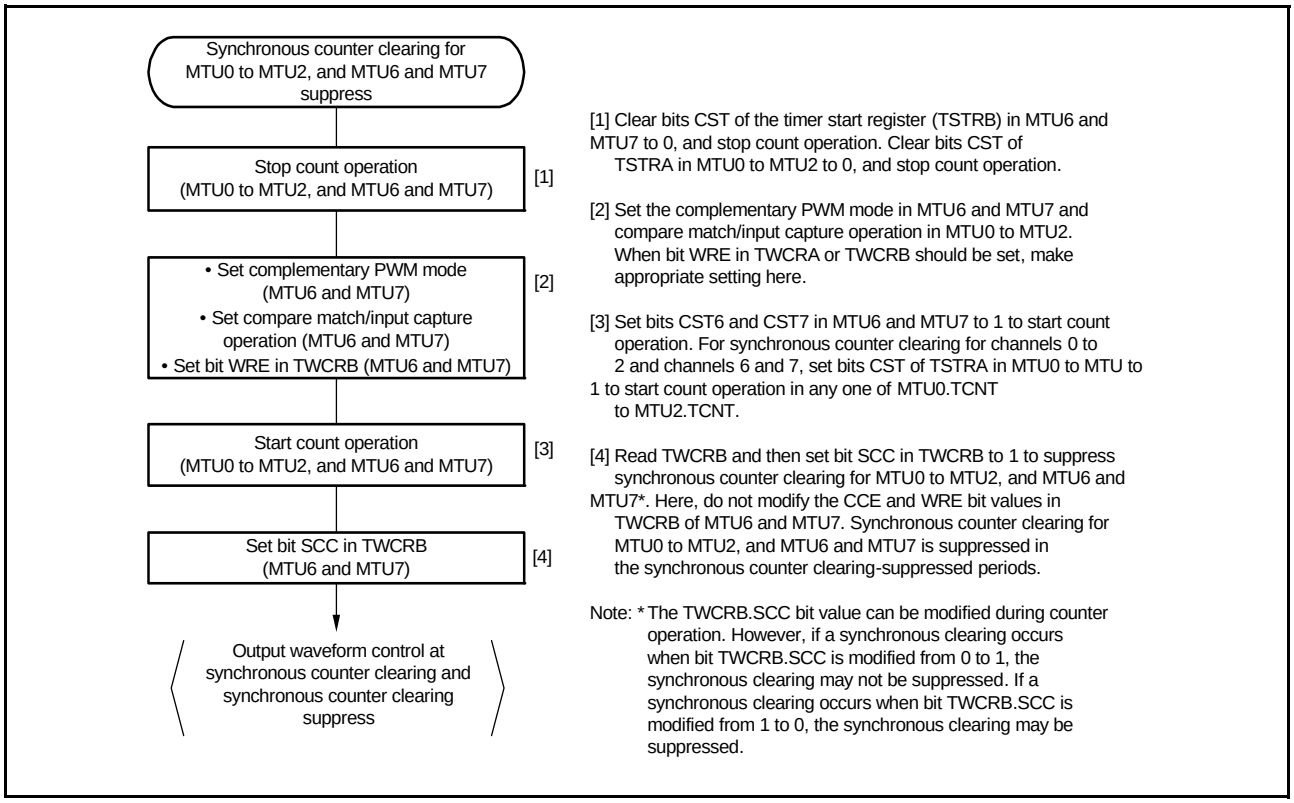


Figure 16.64 Example of Procedure for Suppressing Synchronous Counter Clearing for MTU0 to MTU2, and MTU6 and MTU7

- Examples of Suppression of Synchronous Counter Clearing for MTU0 to MTU2, and MTU6 and MTU7

Figure 16.65 to Figure 16.68 show examples of operation in which channels 6 and 7 operate in complementary PWM mode and synchronous counter clearing for MTU0 to MTU2, and MTU6 and MTU7 is suppressed by setting the SCC bit in TWCRB in MTU6 and MTU7 to 1. In the examples shown in Figure 16.65 to Figure 16.68, synchronous counter clearing occurs at timing (3), (6), (8), and (11) shown in Figure 16.57, respectively. In these examples, the WRE bit in TWCRB in MTU6 and MTU7 is set to 1.

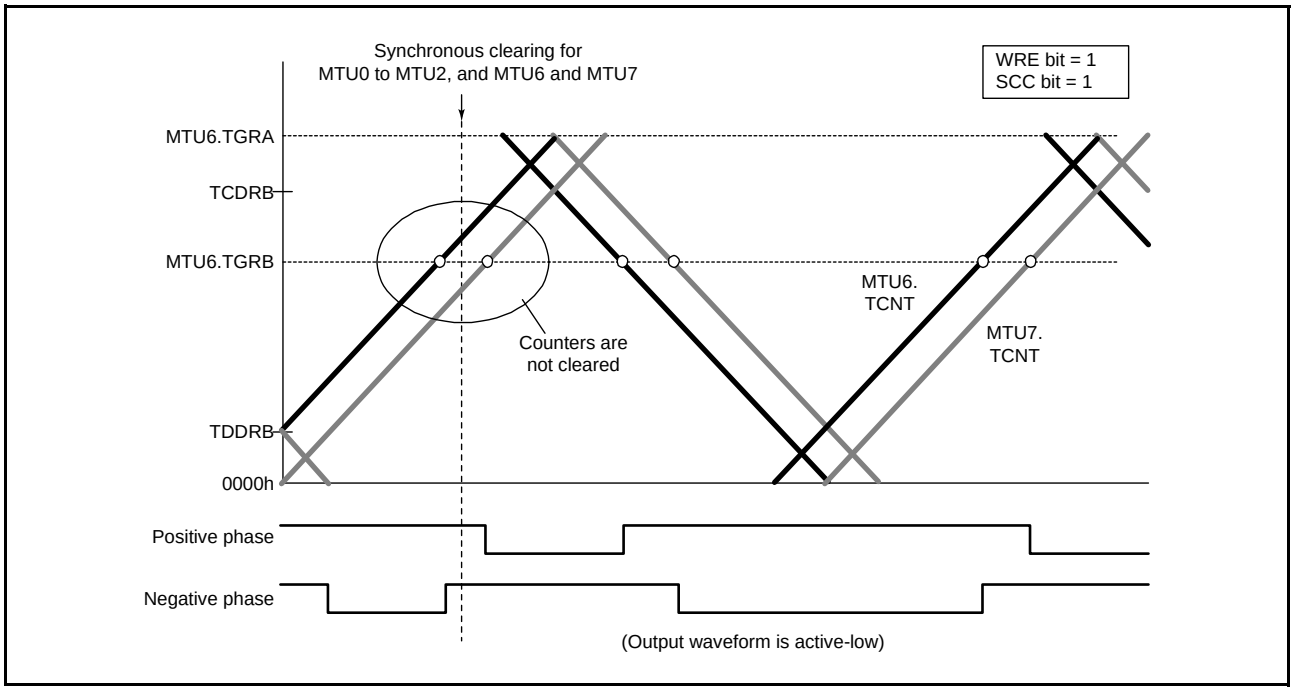


Figure 16.65 Example of Synchronous Clearing in Dead Time during Up-Counting (Timing (3) in Figure 16.57; Bit WRE is 1 and Bit SCC is 1 in TWCRB in MTU6 and MTU7)

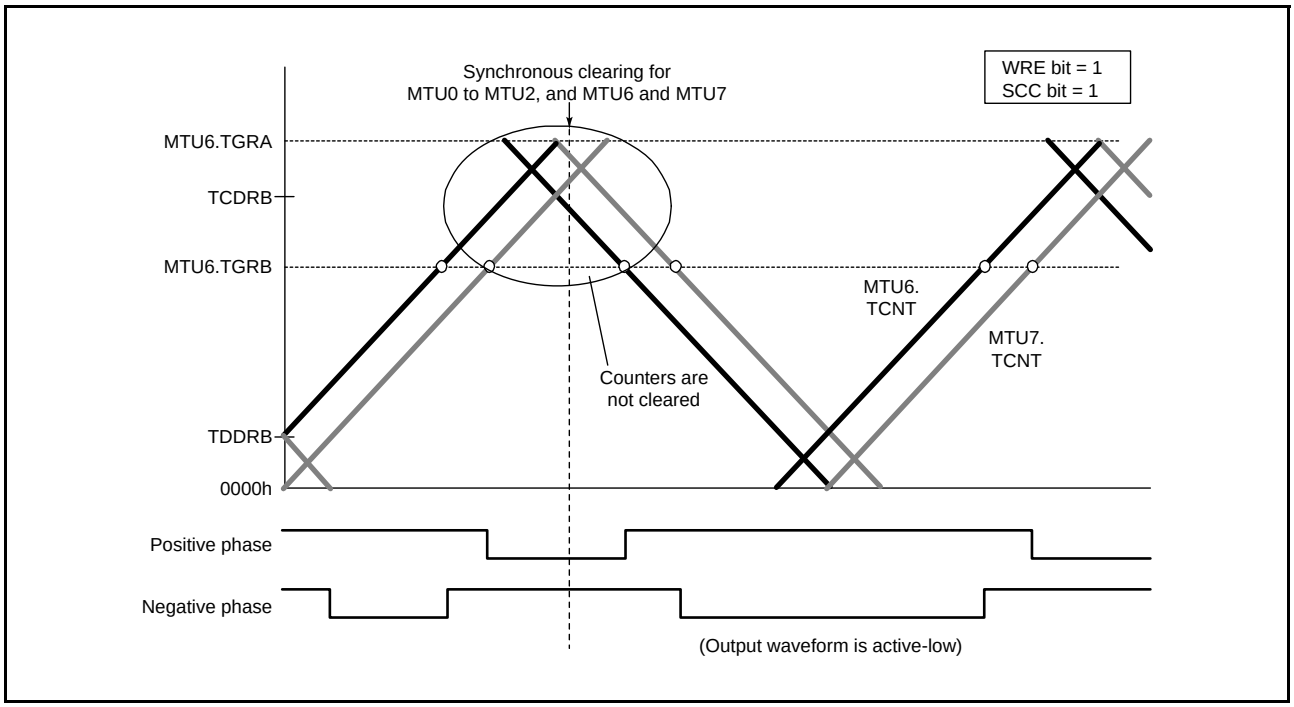


Figure 16.66 Example of Synchronous Clearing in Interval Tb at Crest (Timing (6) in Figure 16.57; Bit WRE is 1 and Bit SCC is 1 in TWCRB in MTU6 and MTU7)

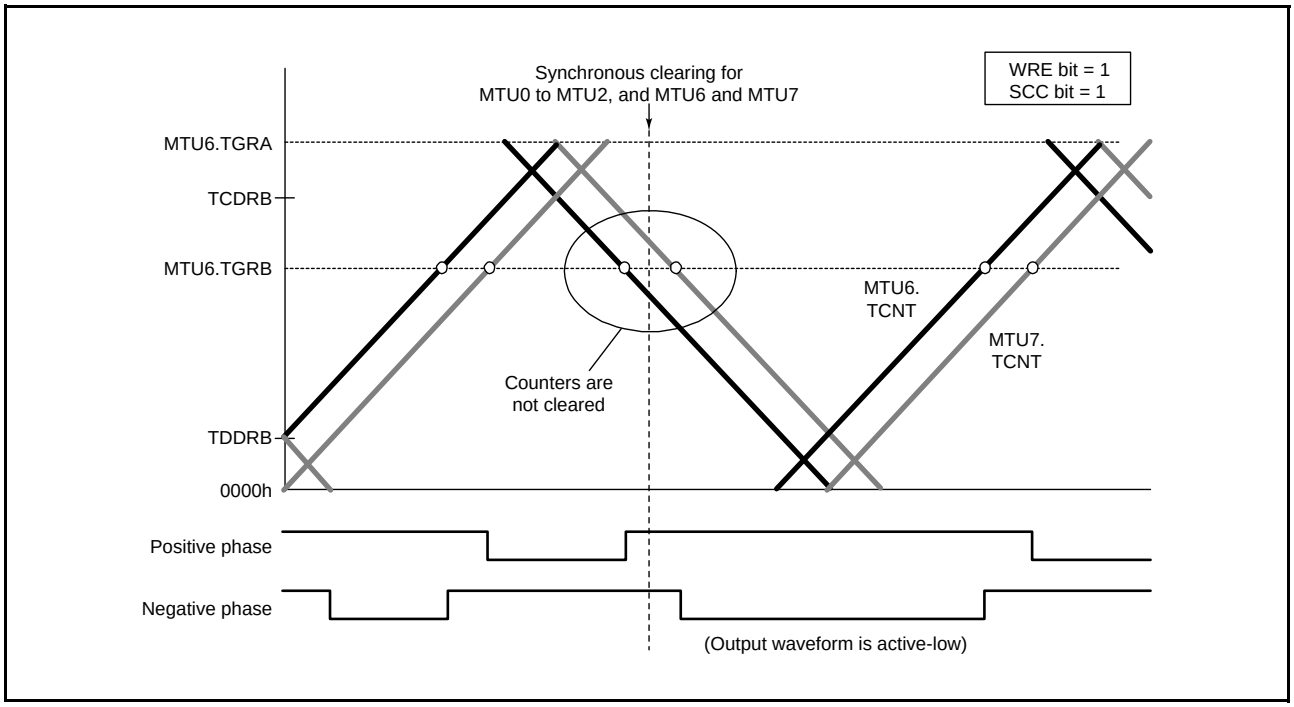


Figure 16.67 Example of Synchronous Clearing in Dead Time during Down-Counting (Timing (8) in Figure 16.57; Bit WRE is 1 and Bit SCC is 1 in TWCRB in MTU6 and MTU7)

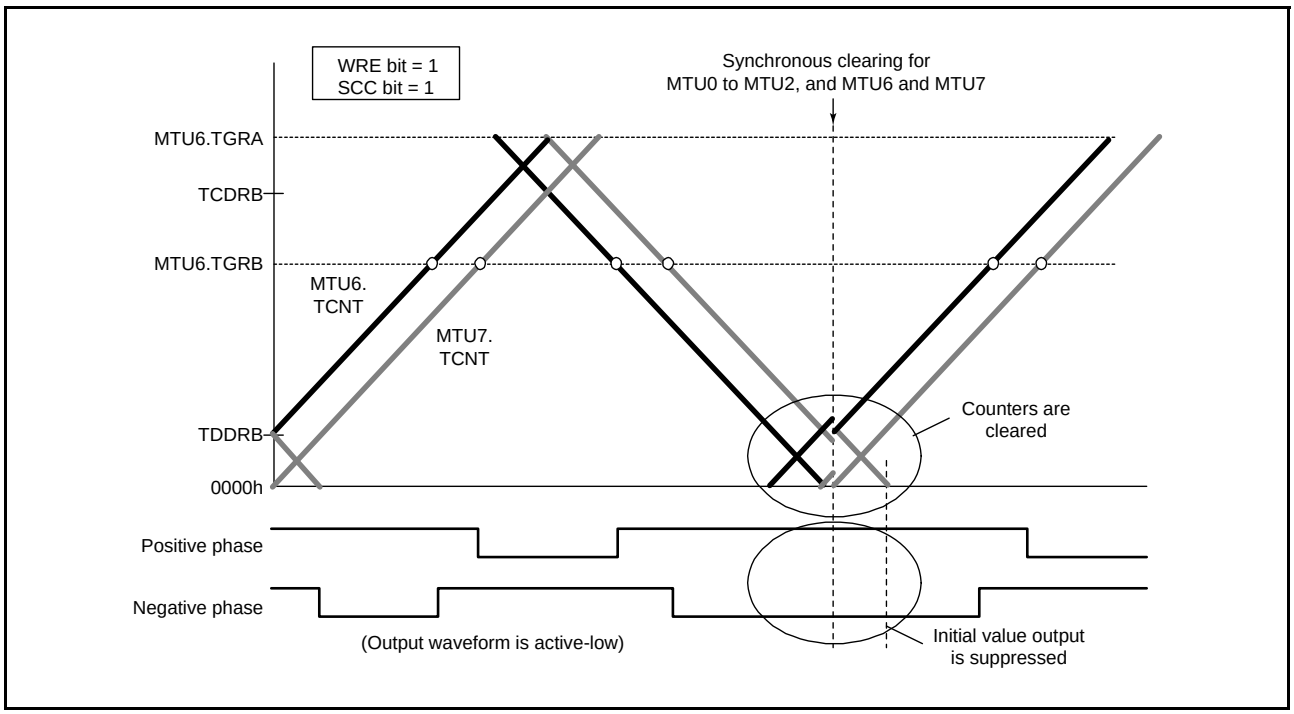


Figure 16.68 Example of Synchronous Clearing in Interval Tb at Trough (Timing (11) in Figure 16.57; Bit WRE is 1 and Bit SCC is 1 in TWCRB in MTU6 and MTU7)

(p) Counter Clearing by MTU3.TGRA (MTU6.TGRA) Compare Match

In complementary PWM mode, MTU3.TCNT, MTU4.TCNT, and TCNTSA (MTU6.TCNT, MTU7.TCNT, and TCNTSB) can be cleared by MTU3.TGRA (MTU6.TGRA) compare match when the CCE bit is set in the timer waveform control register (TWCRA or TWCRB).
Figure 16.69 illustrates an operation example.

Note 1. Use this function only in complementary PWM mode 1 (transfer at crest).
Note 2. Do not specify synchronous clearing by another channel (do not set the SYNC0 to SYNC4 or SYNC6 to SYNC7 bits in the timer synchronous register (TSYRA or TSYRB) to 1 or the CE0A to CE0D and CE1A to CE1D bits in the timer synchronous clear register (TSYCRA or TSYCRB) to 1).
Note 3. Do not set the PWM duty value to 0000h.
Note 4. Do not set the PSYE bit in timer output control register 1 (TOCR1A or TOCR1B) to 1.

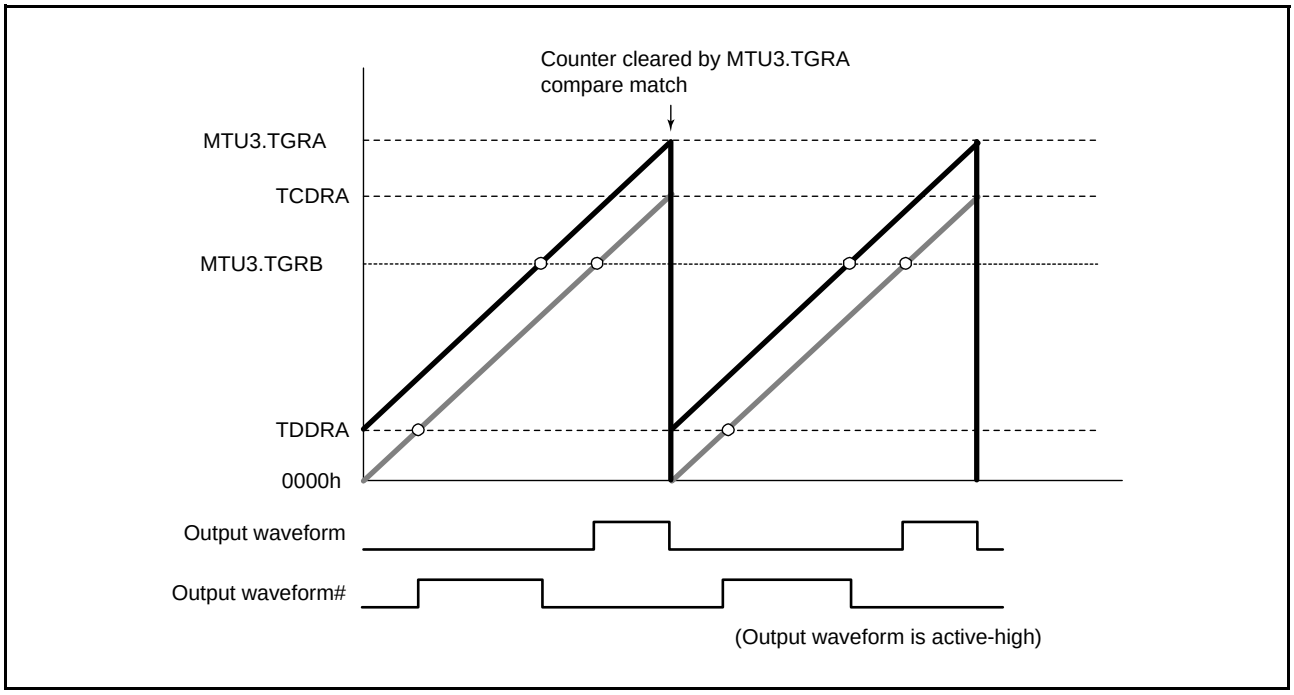


Figure 16.69 Example of Counter Clearing Operation by MTU3.TGRA Compare Match

(q) Example of Waveform Output for Driving AC Synchronous Motor (Brushless DC Motor)

In complementary PWM mode, a brushless DC motor can easily be controlled using the timer gate control register (TGCRA). Figure 16.70 to Figure 16.73 show examples of brushless DC motor driving waveforms created using TGCRA.

To switch the output phases for a 3-phase brushless DC motor by means of external signals detected with a Hall element, etc., clear the TGCRA.FB bit to 0. In this case, the external signals indicating the magnetic pole position should be input to timer input pins MTIOC0A, MTIOC0B, and MTIOC0C in MTU0 (make appropriate settings in ICR for the I/O ports). When an edge is detected at pin MTIOC0A, MTIOC0B, or MTIOC0C, the output on/off state is switched automatically. When the TGCRA.FB bit is 1, the output on/off state is switched when the UF, VF, or WF bit in TGCRA is cleared to 0 or set to 1.

The driving waveforms are output from the 6-phase output pins for complementary PWM mode.

With this 6-phase output, while the output is turned on, chopping output is available through complementary PWM mode output function by setting the N bit or P bit in TGCRA to 1. When the N bit or P bit is 0, the level output is selected. The active level of the 6-phase output (on output level) can be set with the OLSN and OLSP bits in the timer output control register 1A (TOCR1A) regardless of the setting of the N and P bits.

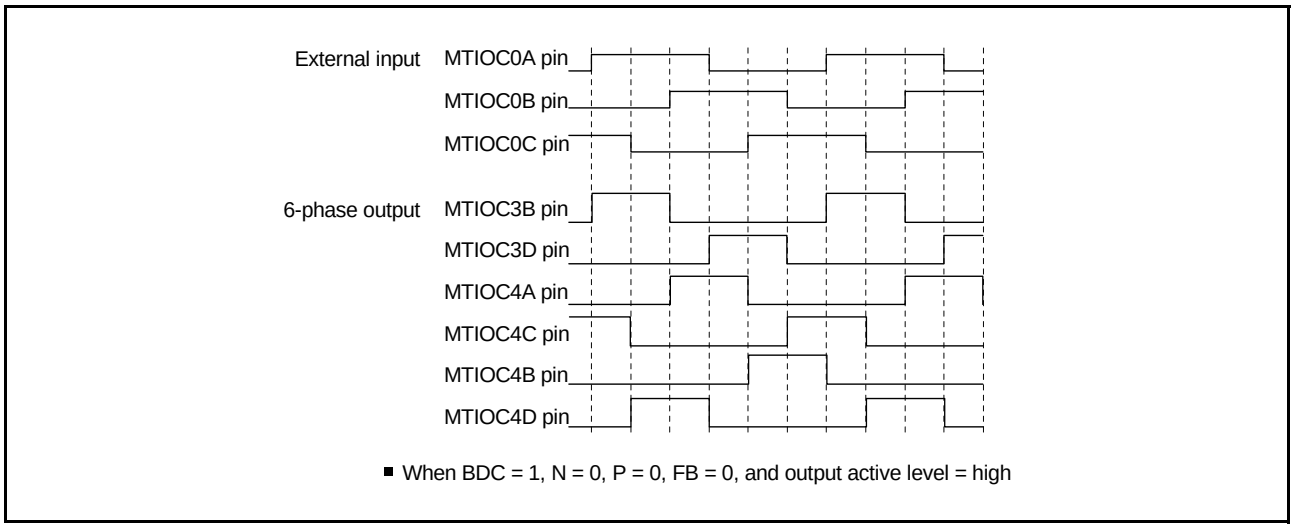


Figure 16.70 Example of Output Phase Switching by External Input (1)

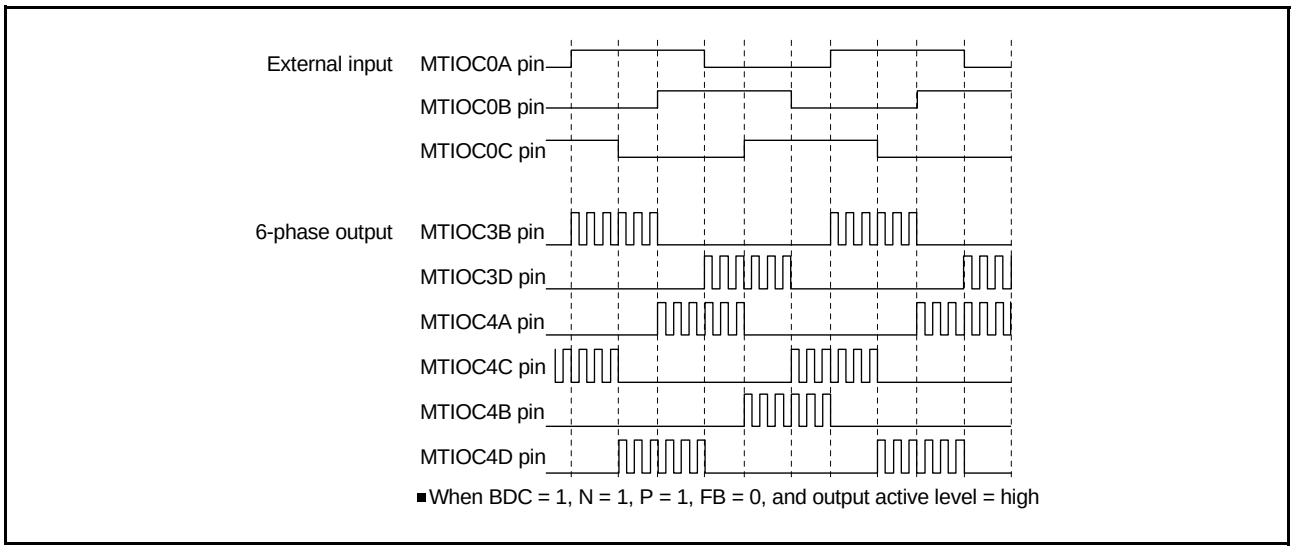


Figure 16.71 Example of Output Phase Switching by External Input (2)

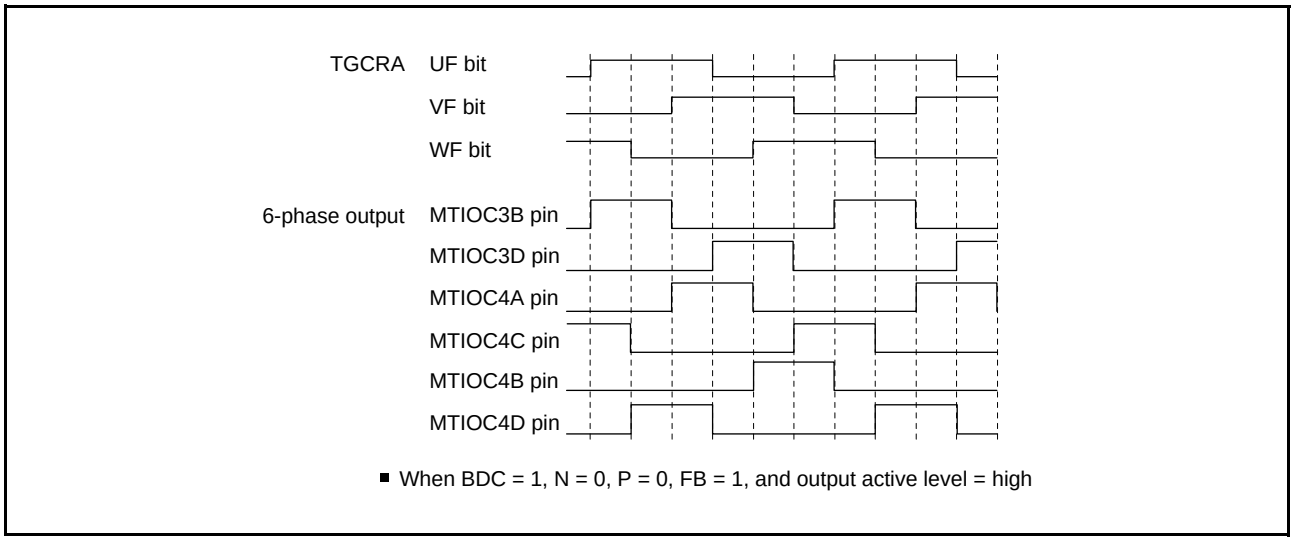


Figure 16.72 Example of Output Phase Switching through UF, VF, and WF Bit Settings (1)

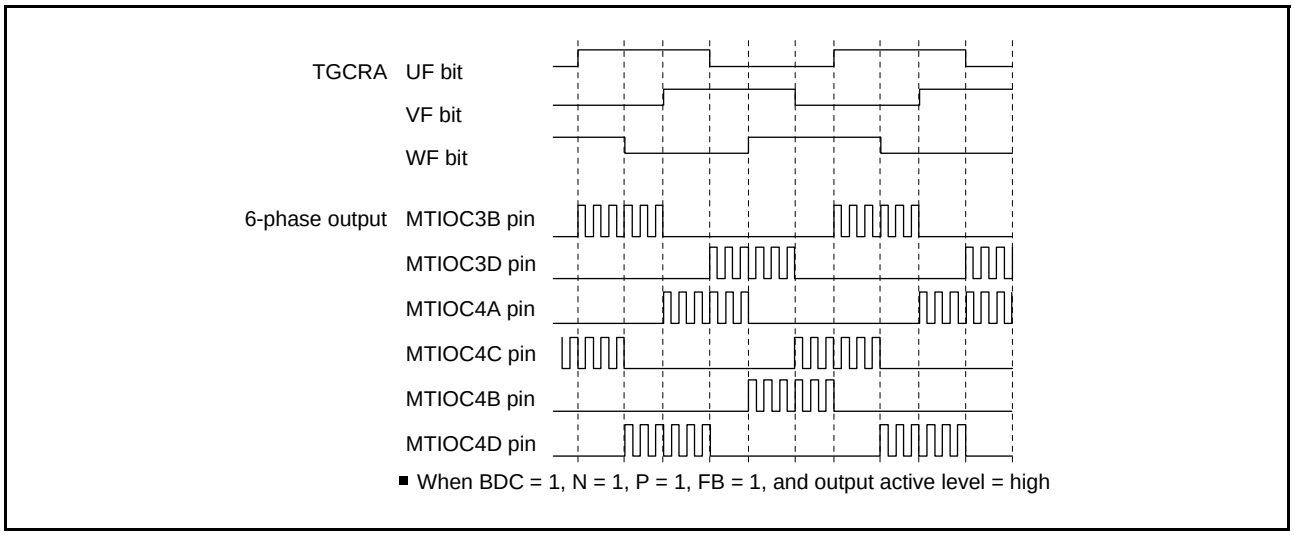


Figure 16.73 Example of Output Phase Switching through UF, VF, and WF Bit Settings (2)

(r) A/D Converter Start Request Setting

In complementary PWM mode, an A/D converter start request can be issued using MTU3.TGRA (MTU6.TGRA) compare match, MTU4.TCNT (MTU7.TCNT) underflow (trough), or compare match on a channel other than MTU3 and MTU4 (MTU6 and MTU7).
When start requests using MTU3.TGRA (MTU6.TGRA) compare match are specified, A/D conversion can be started at the crest of the MTU3.TCNT (MTU6.TCNT) count.
A/D converter start requests can be specified by setting the TTGE bit to 1 in the timer interrupt enable register (TIER).
To issue an A/D converter start request at an MTU4.TCNT (MTU7.TCNT) underflow (trough), set the TTGE2 bit in MTU4.TIER (MTU7.TIER) to 1.

(s) Double Buffer Function in Complementary PWM Mode

In complementary PWM mode 3 (transfer at the crest and trough), the PWM output setting resolution can be improved from ±2 to ±1 by setting the DRS bit in timer mode register 2 (TMDR2A or TMDR2B) to 1.
When setting buffer registers A (MTU3.TGRD, MTU4.TGRC, and MTU4.TGRD), set also buffer registers B (MTU3.TGRE, MTU4.TGRE, and MTU4.TGRF) at the same time. Each buffer register B should be set to the buffer register A value or (buffer register A value – 1). For details of the setting procedure, refer to section 16.3.8 (1)Example of Complementary PWM Mode Setting Procedure

Note 1. When a buffer register B is set to the buffer register A value, symmetric PWM waveforms are output. When a buffer register B is set to (buffer register A value – 1), asymmetric PWM waveforms are output.

Figure 16.74 shows an example of double buffer operation.
Each register data is transferred as follows.

- After MTU4.TGRD (buffer A) is written to, data is transferred from MTU4.TGRD (buffer A) to Temp3A (temporary A) and from MTU4.TGRF (buffer B) to Temp3B (temporary B).
- With timing (1) in the figure, data is transferred from Temp3A (temporary A) to MTU4.TGRB (compare).
- With timing (2) in the figure, data is transferred from Temp3B (temporary B) to MTU4.TGRB (compare).

In the crest interval (Tb interval at crest), the compare register and temporary register A are valid; in the trough interval (Tb interval at trough), the compare register and temporary register B are valid.

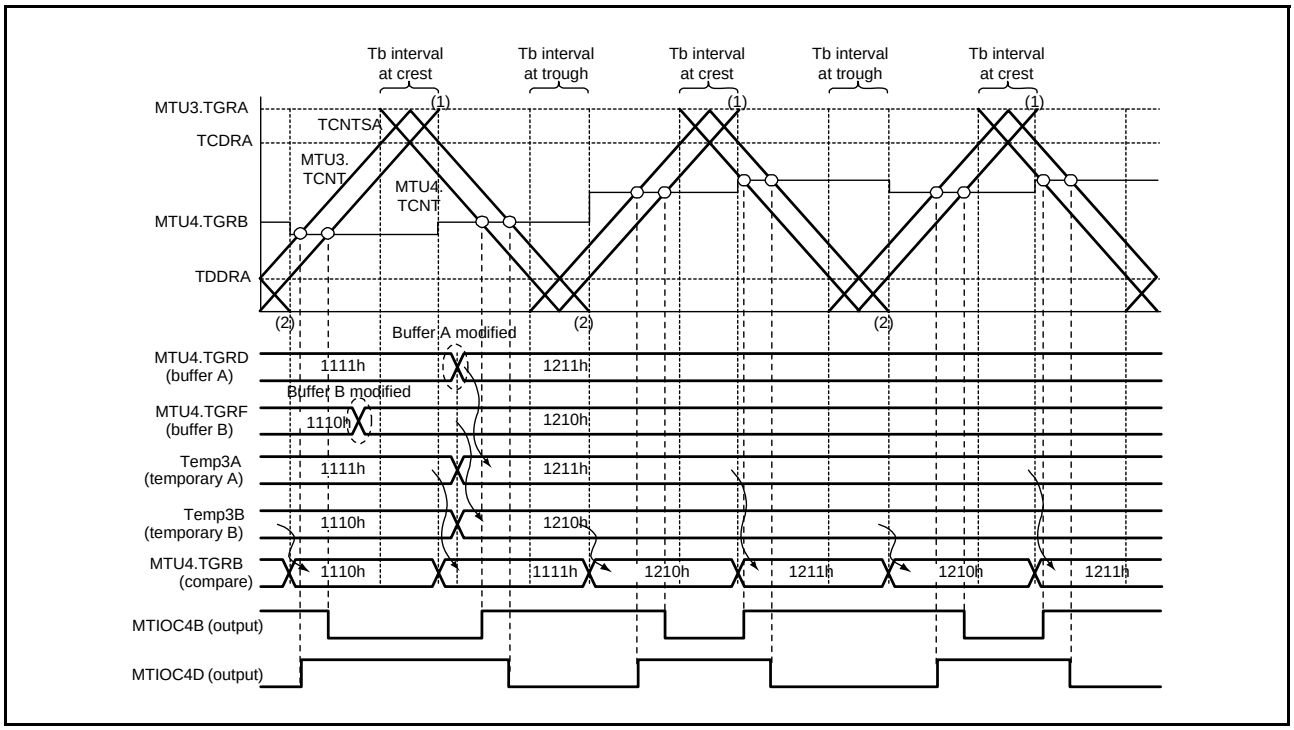


Figure 16.74 Example of Double Buffer Operation

Figure 16.75 shows an example when the buffer write value is smaller than the TDDRA value, and Figure 16.76 shows an example when the write value is greater than TCDRA.

In the crest interval, the output is controlled according to the compare match with the compare register or temporary register A; in the trough interval, the output is controlled according to the compare match with the compare register or temporary register B.

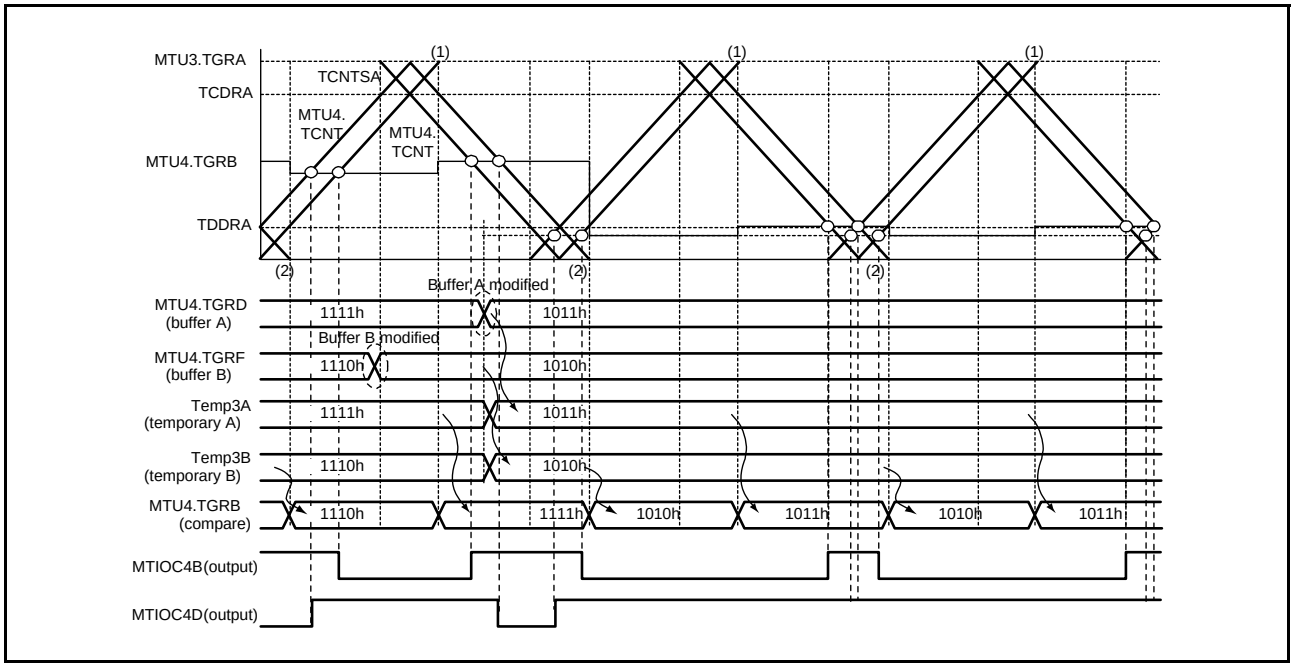


Figure 16.75 Example of Double Buffer Operation (Buffer Write Value is Smaller than TDDRA)

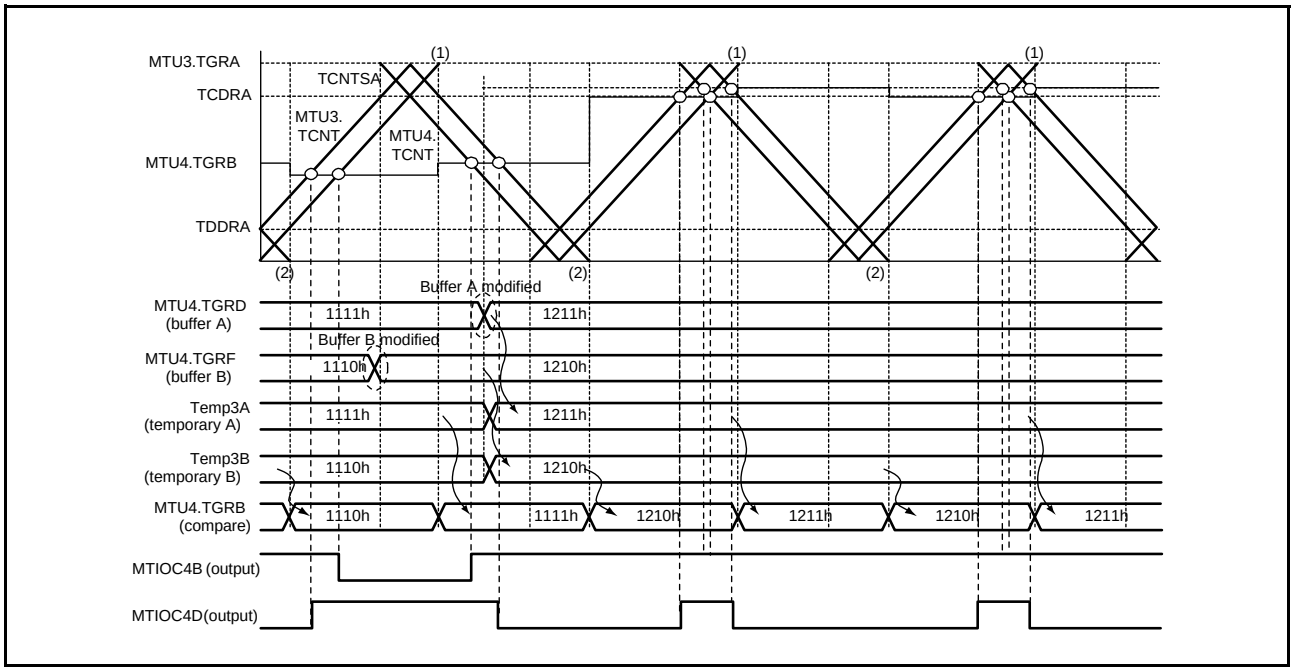


Figure 16.76 Example of Double Buffer Operation (Buffer Write Value is Greater than TCDRA)

(3) Interrupt Skipping Function 1 in Complementary PWM Mode

Interrupts TGIA3 (TGIA6) (at the crest) and TCIV4 (TCIV7) (at the trough) in MTU3 and MTU4 (MTU6 and MTU7) can be skipped up to seven times by making settings in the timer interrupt skipping set register 1 (TITCR1A or TITCR1B).

Transfers from a buffer register to a temporary register or a compare register can be skipped in coordination with interrupt skipping by making settings in the timer buffer transfer register (TBTERA or TBTERB). For the linkage with buffer registers, refer to description (c), Buffer Transfer Control Linked with Interrupt Skipping, below.

A/D converter start requests generated by the A/D converter start request delaying function can also be skipped in coordination with interrupt skipping by making settings in the timer A/D converter request control register (MTU4.TADCR or MTU7.TADCR). For the linkage with the A/D converter start request delaying function, refer to section 16.3.9, A/D Converter Start Request Delaying Function.

The timer interrupt skipping setting register 1 (TITCR1A or TITCR1B) should be set while interrupt skipping function 1 is selected by setting the TITM bit to 0 in the timer interrupt skipping mode register (TITMRA or TITMRB) and TGIA3 (TGIA6) and TCIV4 (TCIV7) interrupt requests are disabled by the settings of MTU3.TIER and MTU4.TIER (MTU6.TIER and MTU7.TIER) under the conditions in which TGFA3 (TGFA6) and TCFV4 (TCFV7) flag settings by compare match never occur in TITCR1A (TITCR1B). Before changing the skipping count, be sure to clear the T3AEN (T6AEN) and T4VEN (T7VEN) bits to 0 to clear the skipping counter.

(a) Example of Interrupt Skipping Function 1 Setting Procedure

Figure 16.77 shows an example of the interrupt skipping function 1 setting procedure. Figure 16.78 shows the periods during which interrupt skipping count can be changed.

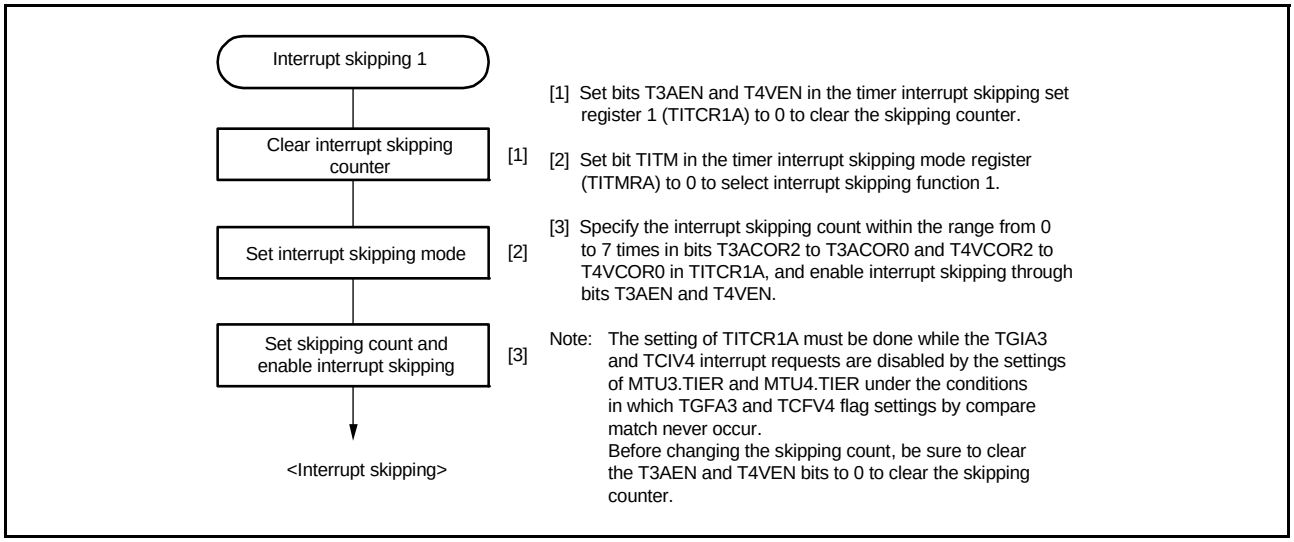


Figure 16.77 Example of Interrupt Skipping Function 1 Setting Procedure

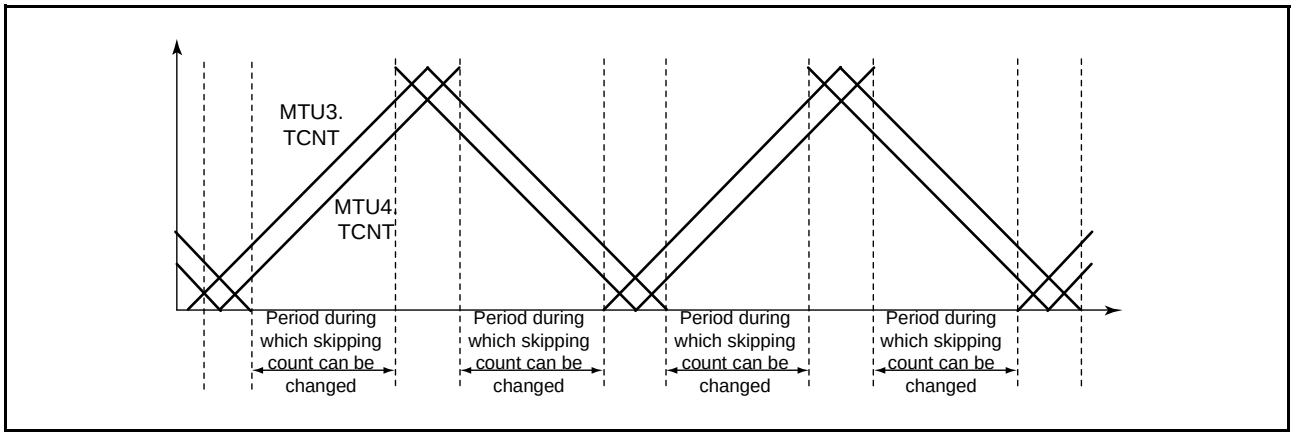


Figure 16.78 Periods during which Interrupt Skipping Count can be Changed

(b) Example of Interrupt Skipping Function 1

Figure 16.79 shows an example of TGIA3 (TGIA6) interrupt skipping in which the interrupt skipping count is set to three by the T3ACOR (T6ACOR) bits and the T3AEN (T6AEN) bit is set to 1 in the timer interrupt skipping set register 1 (TITCR1A or TITCR1B).

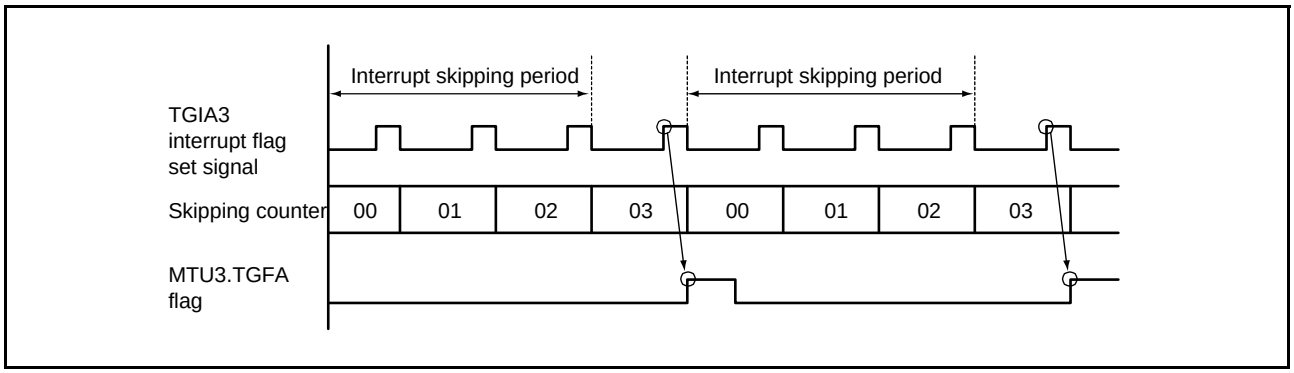


Figure 16.79 Example of Interrupt Skipping Function 1

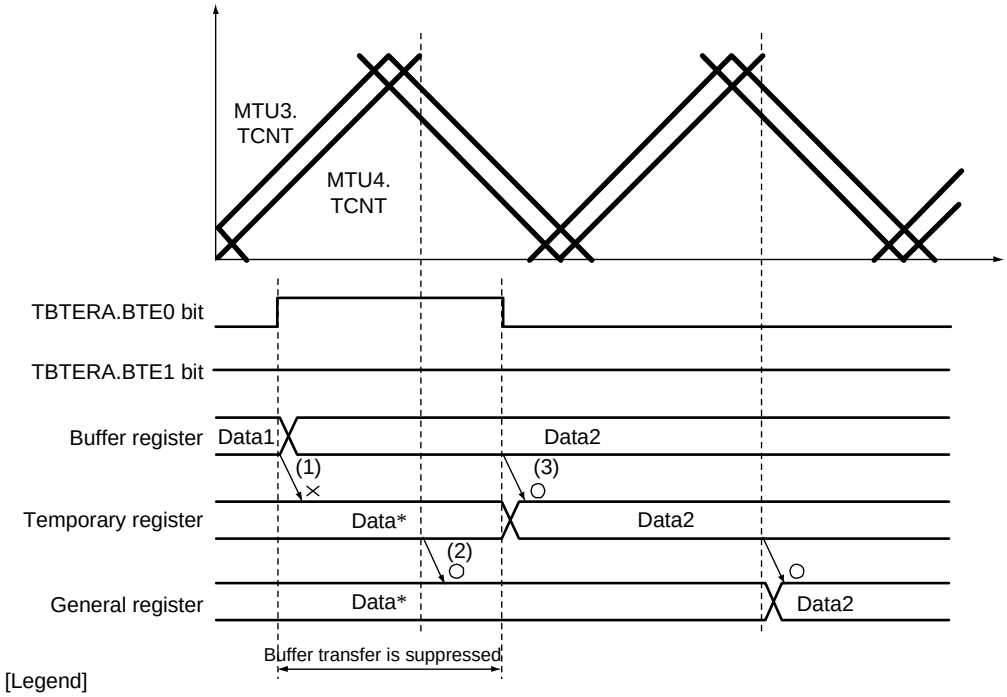
(c) Buffer Transfer Control Linked with Interrupt Skipping

In complementary PWM mode, whether to transfer data from a buffer register to a temporary register and whether to link the transfer with interrupt skipping can be specified with the BTE[1:0] bits in the timer buffer transfer set register (TBTERA or TBTERB).

Figure 16.80 shows an example of operation when buffer transfer is disabled (BTE[1:0] = 01b). While this setting is valid, data is not transferred from the buffer register to the temporary register.

Figure 16.81 shows an example of operation when buffer transfer is linked with interrupt skipping (BTE[1:0] = 10b). While this setting is valid, data is not transferred from the buffer register outside the buffer transfer-enabled period. Note that the buffer transfer-enabled period depends on the T3AEN (T6AEN) and T4VEN (T7VEN) bit settings in the timer interrupt skipping set register 1 (TITCR1A or TITCR1B). Figure 16.82 shows the relationship between the T3AEN (T6AEN) and T4VEN (T7VEN) bit settings in TITCR1A (TITCR1B) and buffer transfer-enabled period.

Note 1. This function must always be used in combination with interrupt skipping function 1.
When interrupt skipping is disabled (the T3AEN and T4VEN (T6AEN and T7VEN) bits in the timer interrupt skipping set register 1 (TITCR1A or TITCR1B) are cleared to 0 or the skipping count set bits (T3ACOR and T4VCOR (T6ACOR and T7VCOR)) in TITCR1A (TITCR1B) are cleared to 0), make sure that buffer transfer is not linked with interrupt skipping (clear the BTE1 bit in TBTERA or TBTERB to 0).
If buffer transfer is linked with interrupt skipping while interrupt skipping is disabled, buffer transfer is never performed.

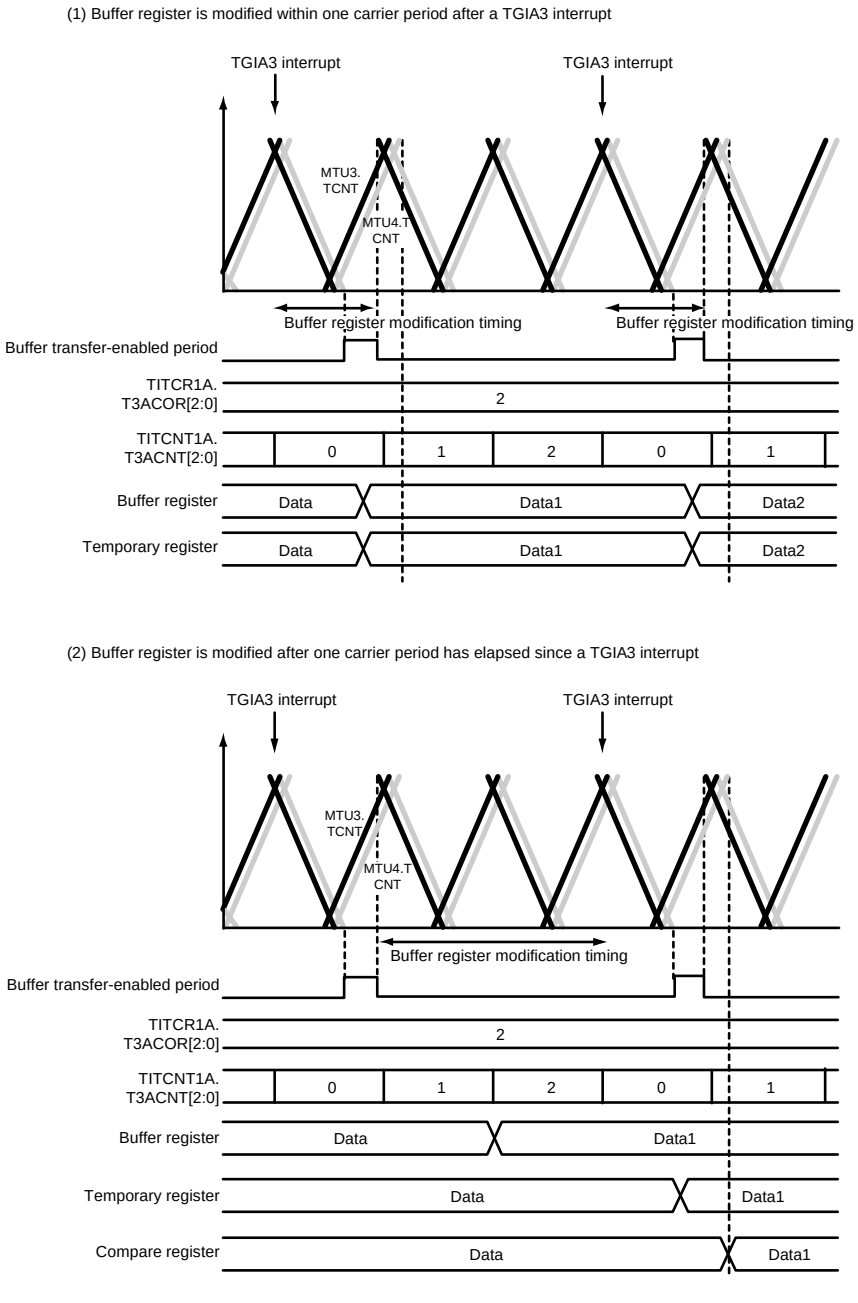


[Legend]

(1) No data is transferred from the buffer register to the temporary register in the buffer transfer-disabled period (bits BTE[1:0] in TBTERA are set to 01b).
(2) Data is transferred from the temporary register to the general register even in the buffer transfer-disabled period.
(3) After buffer transfer is enabled, data is transferred from the buffer register to the temporary register.

Note: * When buffer transfer at the crest is selected.

Figure 16.80 Example of Operation when Buffer Transfer is Disabled (BTE[1:0] = 01b)



Note: Bits MD[3:0] in MTU3.TMDR are set to 1101b. (Buffer transfer at the crest is selected.)
The skipping count is set to two.
Bit T3AEN in TITCR1A is set to 1 and bit T4VEN is set to 0.

Figure 16.81 Example of Operation when Buffer Transfer is Linked with Interrupt Skipping (BTE[1:0] = 10b)

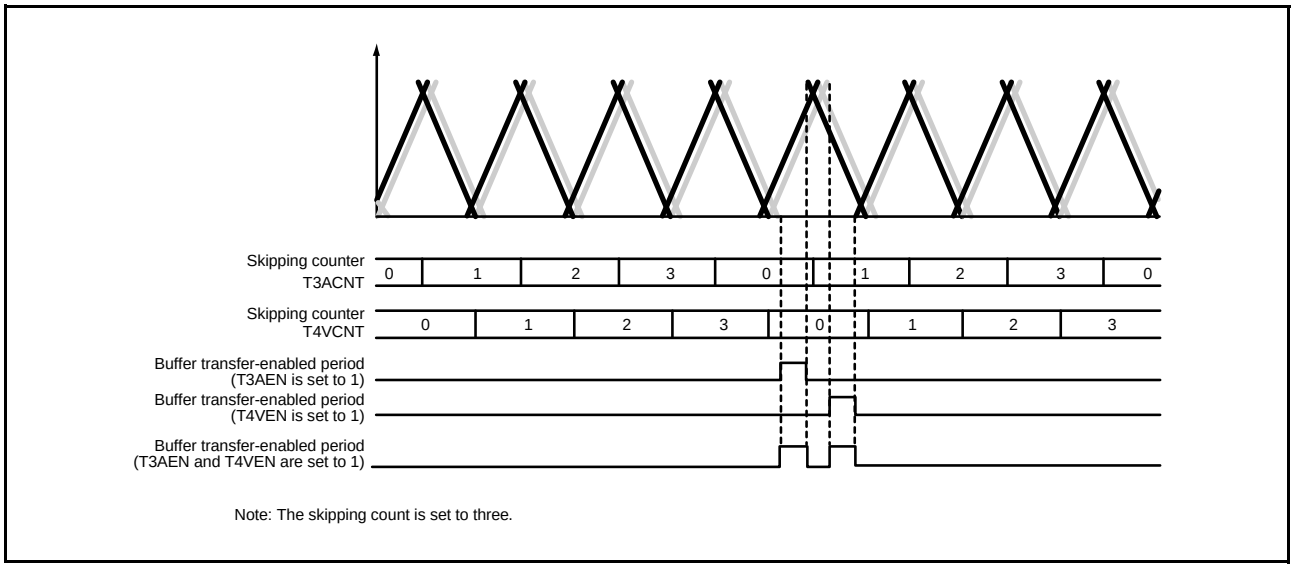


Figure 16.82 Relationship between Bits T3AEN and T4VEN in TITCR1A and Buffer Transfer-Enabled Period

(4) Complementary PWM Mode Output Protection Functions

The MTU3 provides the following protection functions for complementary PWM mode output.

(a) Register and Counter Miswrite Prevention Function

With the exception of the buffer registers, which can be modified at any time, access by the CPU can be enabled or disabled for the mode registers, control registers, compare registers, and counters used in complementary PWM mode by means of the RWE bit in the timer read/write enable register (TRWERA or TRWERB). The applicable registers are some of the registers in MTU3, MTU4, MTU6, and MTU7 shown below:
43 registers in total
MTU3.TCR, MTU4.TCR, MTU3.TMDR1, MTU4.TMDR1, MTU3.TIORH,
MTU4.TIORH, MTU3.TIORL, MTU4.TIORL, MTU3.TIER, MTU4.TIER,
MTU3.TCNT, MTU4.TCNT, MTU3.TGRA, MTU4.TGRA, MTU3.TGRB, MTU4.TGRB,
TOERA, TOCR1A, TOCR2A, TGCRA, TCDRA, TDDRA
MTU6.TCR, MTU7.TCR, MTU6.TMDR1, MTU7.TMDR1, MTU6.TIORH, MTU7.TIORH,
MTU6.TIORL, MTU7.TIORL, MTU6.TIER, MTU7.TIER, MTU6.TCNT, MTU7.TCNT,
MTU6.TGRA, MTU7.TGRA, MTU6.TGRB, MTU7.TGRB,
TOERB, TOCR1B, TOCR2B, TCDRB, and TDDRB
This function can disable CPU access to the mode registers, control registers, and counters to prevent miswriting due to CPU runaway. In the access-disabled state, the applicable registers are read as undefined and writing to these registers is ignored.

(b) Halting of PWM Output by External Signal

The 6-phase PWM output pins can be set to the high-impedance state automatically by inputting specified external signals.
See section 17, Port Output Enable 3 (POE3), for details.

(c) Halting of PWM Output when Oscillator is Stopped

Upon detecting that the clock input to this the RX62T has stopped, the 6-phase PWM output pins are automatically set to the high-impedance state. Note that the pin states are not guaranteed when the clock is restarted.
See section 8.10, Oscillation Stop Detection Function.

16.3.9 A/D Converter Start Request Delaying Function

A/D converter start requests can be issued in MTU4 or MTU7 by making settings in the timer A/D converter start request control register (MTU4.TADCR or MTU7.TADCR), timer A/D converter start request cycle set registers (MTU4.TADCORA and MTU4.TADCORB, or MTU7.TADCORA and MTU7.TADCORB), and timer A/D converter start request cycle set buffer registers (MTU4.TADCOBRA and MTU4.TADCOBRB, or MTU7.TADCOBRA and MTU7.TADCOBRB).

The A/D converter start request delaying function compares MTU4.TCNT with MTU4.TADCORA or MTU4.TADCORB (MTU7.TCNT with MTU7.TADCORA or MTU7.TADCORB), and when their values match, the function issues a respective A/D converter start request (TRG4AN or TRG4BN (TRG7AN or TRG7BN)).

A/D converter start requests (TRG4AN and TRG4BN (TRG7AN and TRG7BN)) can be skipped in coordination with interrupt skipping by making settings in the ITA3AE, ITA4VE, ITB3AE, and ITB4VE bits in MTU4.TADCR (the ITA6AE, ITA7VE, ITB6AE, and ITB7VE bits in MTU7.TADCR).

(1) Example of Procedure for Specifying A/D Converter Start Request Delaying Function

Figure 16.83 shows an example of procedure for specifying the A/D converter start request delaying function.

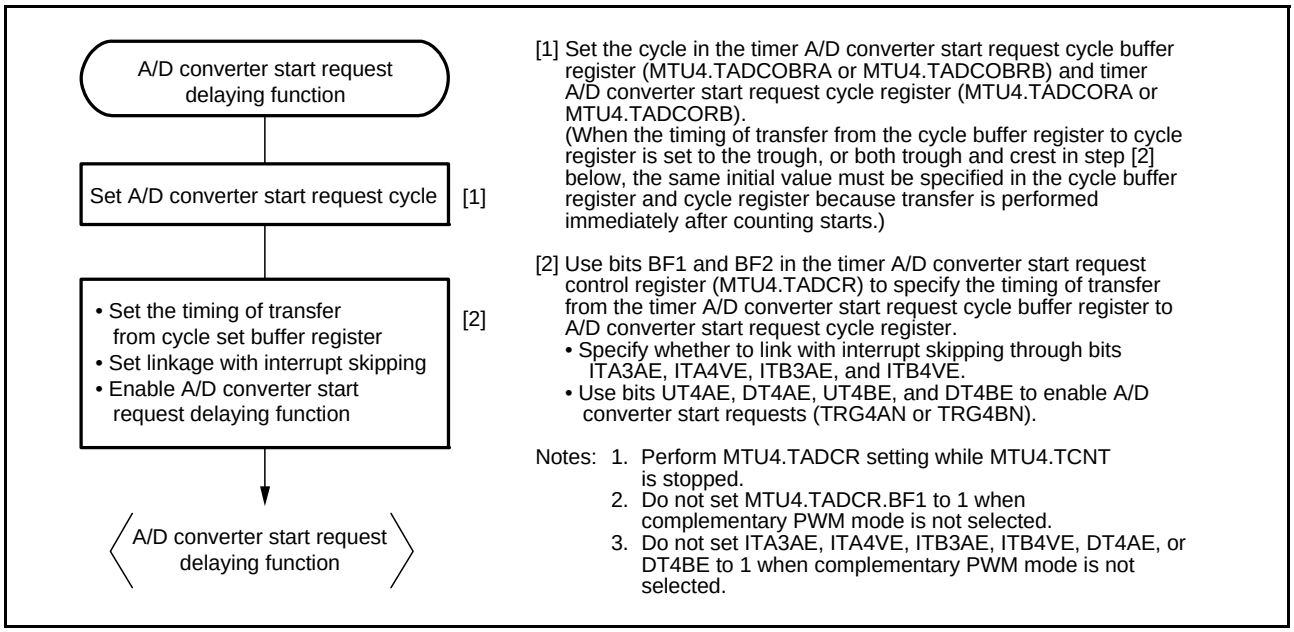


Figure 16.83 Example of Procedure for Specifying A/D Converter Start Request Delaying Function

(2) Basic Example of A/D Converter Start Request Delaying Function Operation

Figure 16.84 shows a basic example of A/D converter start request signal (TRG4AN (TRG7AN)) operation when the trough of MTU4.TCNT (MTU7.TCNT) is specified for the buffer transfer timing and an A/D converter start request signal is output during MTU4.TCNT (MTU7.TCNT) down-counting.

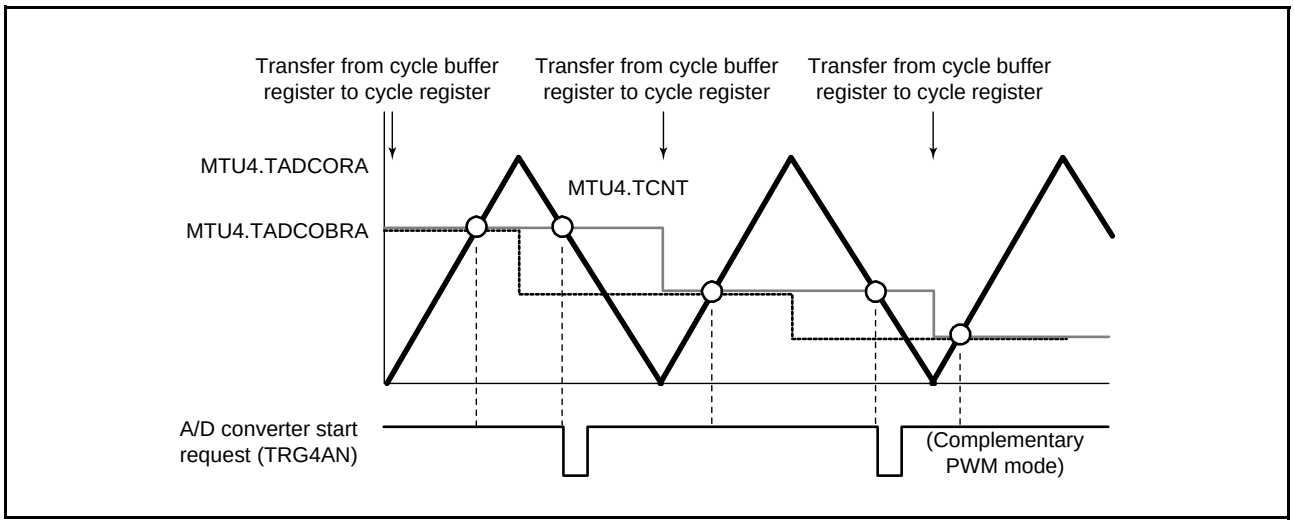


Figure 16.84 Basic Example of A/D Converter Start Request Signal (TRG4AN) Operation

(3) Buffer Transfer

The data in the timer A/D converter start request cycle set registers (MTU4.TADCORA and MTU4.TADCORB, or MTU7.TADCORA and MTU7.TADCORB) is updated by writing data to the timer A/D converter start request cycle set buffer registers (MTU4.TADCOBRA and MTU4.TADCOBRB, or MTU7.TADCOBRA and MTU7.TADCOBRB). Data is transferred from the buffer registers to the respective cycle set registers at the timing selected with the BF[1:0] bits in the timer A/D converter start request control register (MTU4.TADCR or MTU7.TADCR).
In complementary PWM mode, data is also transferred from the timer A/D converter start request cycle set buffer registers to the timer A/D converter start request cycle set registers when timer general register D (MTU4.TGRD or MTU7.TGRD) is updated.

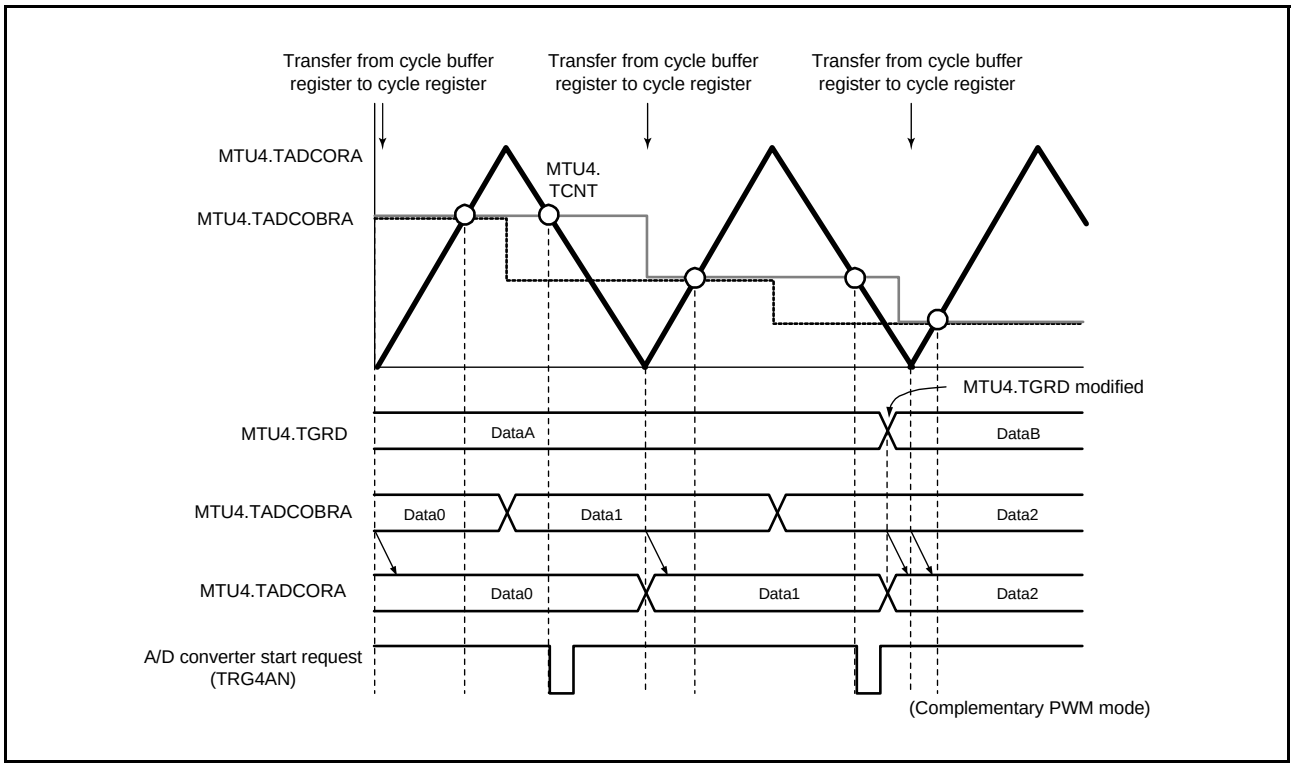


Figure 16.85 Example of A/D Converter Start Request Signal (TRG4AN) and Buffer Transfer Operation

(4) A/D Converter Start Request Delaying Function Linked with Interrupt Skipping Function 1

A/D converter start requests (TRG4AN and TRG4BN (TRG7AN and TRG7BN)) can be issued in coordination with interrupt skipping 1 by making settings in the ITA3AE, ITA4VE, ITB3AE, and ITB4VE (ITA6AE, ITA7VE, ITB6AE, and ITB7VE) bits in the timer A/D converter start request control register (MTU4.TADCR or MTU7.TADCR).
Figure 16.86 shows an example of A/D converter start request signal (TRG4AN (TRG7AN)) operation when TRG4AN (TRG7AN) output is enabled during MTU4.TCNT (MTU7.TCNT) up-counting and down-counting and A/D converter start requests are linked with interrupt skipping 1.
Figure 16.87 shows another example of A/D converter start request signal (TRG4AN (TRG7AN)) operation when TRG4AN (TRG7AN) output is enabled during MTU4.TCNT (MTU7.TCNT) up-counting and A/D converter start requests are linked with interrupt skipping 1.

Note: • This function should be used in combination with interrupt skipping 1.
When interrupt skipping is disabled (the T3AEN and T4VEN (T6AEN and T7VEN) bits in the timer interrupt skipping set register (TITCR1A (TITCR1B)) are cleared to 0 or the skipping count set bits (T3ACOR and T4VCOR (T6ACOR and T7VCOR)) in TITCR1A (TITCR1B) are cleared to 0), make sure that A/D converter start requests are not linked with interrupt skipping 1 (clear the ITA3AE, ITA4VE, ITB3AE, and ITB4VE (ITA6AE, ITA7VE, ITB6AE, and ITB7VE) bits in the timer A/D converter start request control register (MTU4.TADCR (MTU7.TADCR)) to 0).
When this function is used, MTU4.TADCORA and MTU4.TADCORB (MTU7.TADCORA and MTU7.TADCORB) should be set with the value ranging 0002h to the value set in TCDRA minus 2 (value set in TCDRB minus 2).

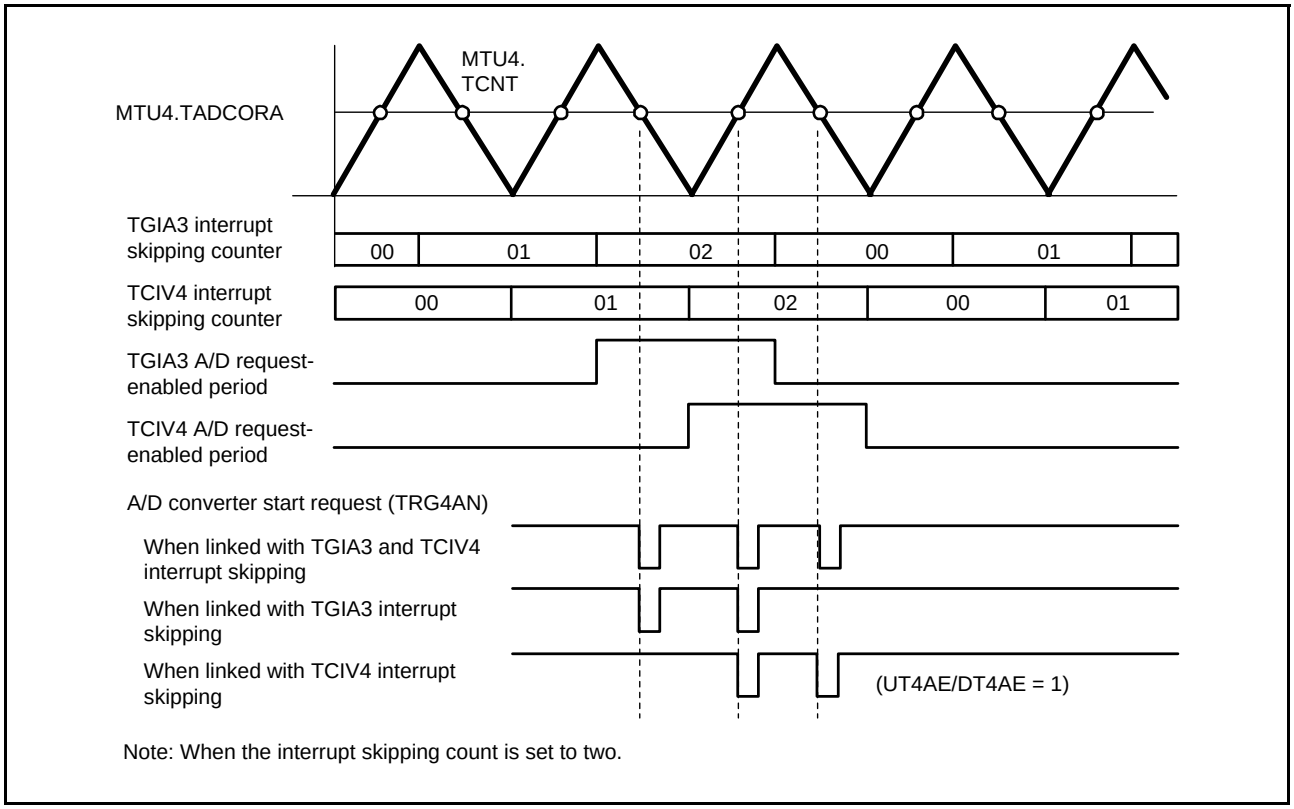


Figure 16.86 Example of A/D Converter Start Request Signal (TRG4AN) Operation Linked with Interrupt Skipping Function 1 (UT4AE and DT4AE = 1)

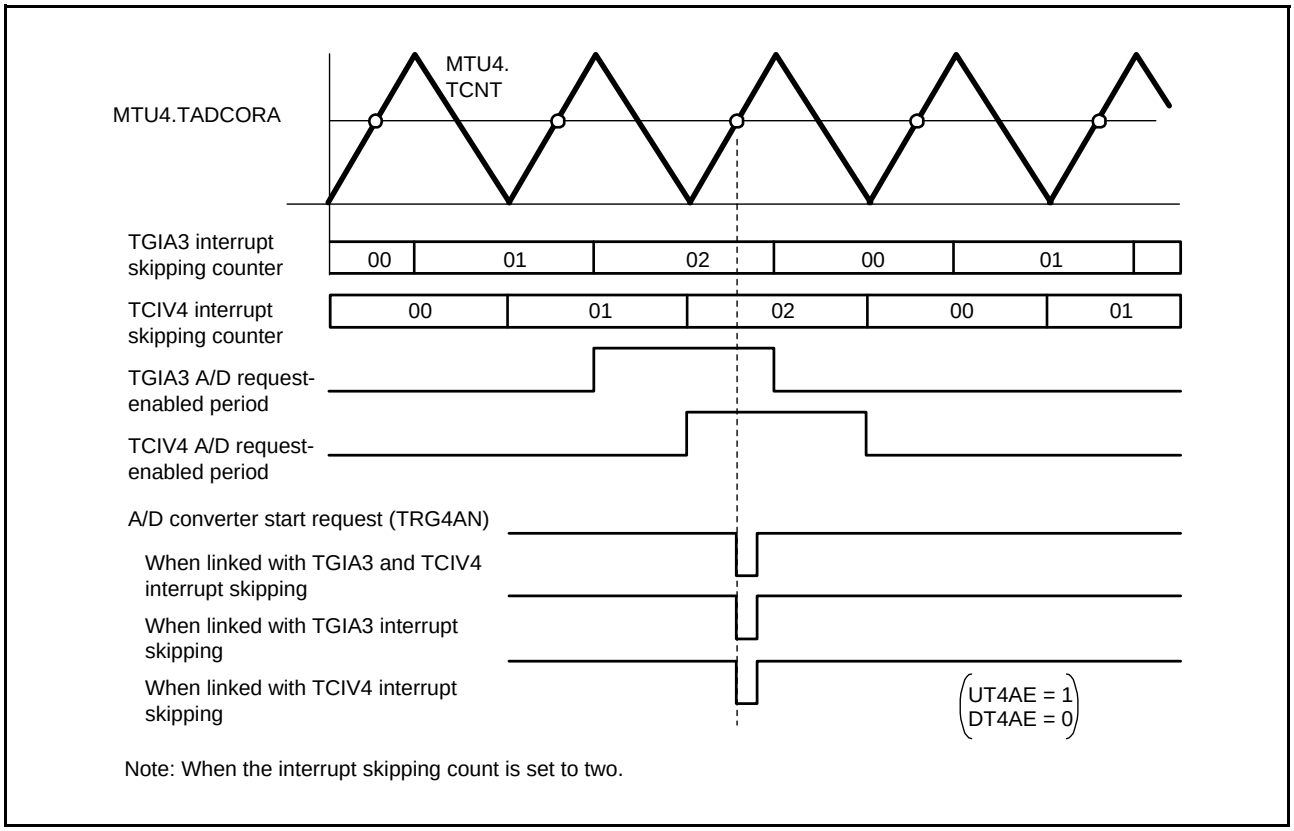


Figure 16.87 Example of A/D Converter Start Request Signal (TRG4AN) Operation Linked with Interrupt Skipping Function 1 (UT4AE = 1, DT4AE = 0)

(5) A/D Converter Start Request Delaying Function Linked with Interrupt Skipping Function 2

By setting the TITM bit to 1 in the timer interrupt skipping mode register (TITMRA or TITMRB), the counter starts down-counting from the value (0 to 7) set in the TRG4COR[2:0] (TRG7COR[2:0]) bits in timer interrupt skipping set register 2 (TITCR2A (TITCR2B)) every time an A/D converter start trigger (TGR4AN or TRG4BN (TGR7AN or TRG7BN)) is generated. When the counter value reaches 0 and is reloaded, the TRG4AN and TRG4BN (TRG7AN and TRG7BN) interrupts become valid and an A/D converter start request signal (TRG4ABN (TRG7ABN)) is output. This function is valid only when the A/D converter request delaying function is enabled.

(a) Example of Procedure for Setting Interrupt Skipping Function 2

Figure 16.88 shows an example of procedure for setting interrupt skipping function 2.

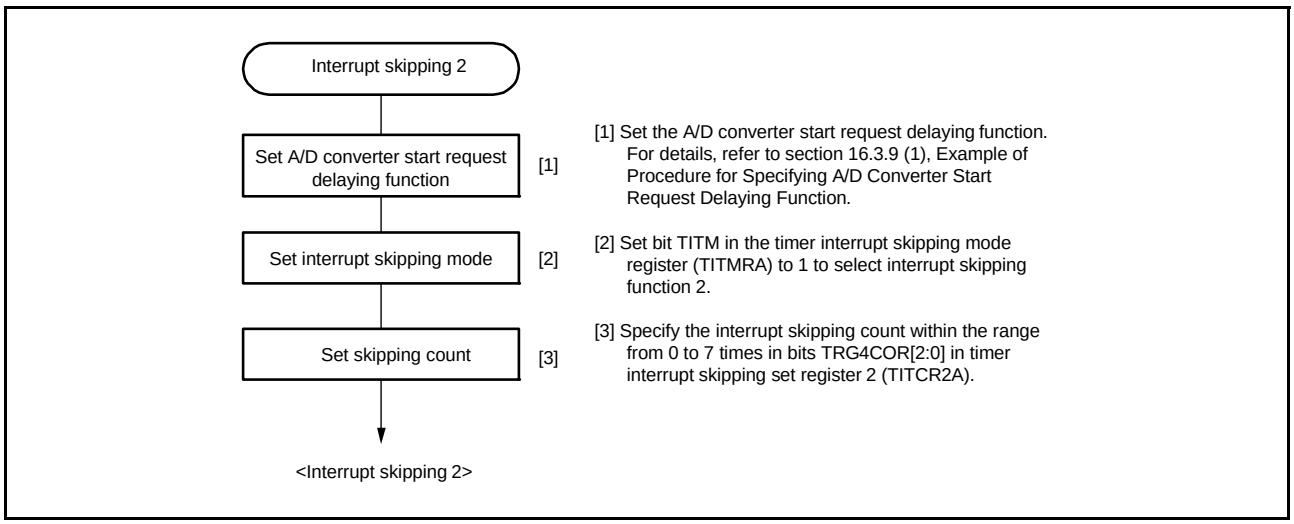


Figure 16.88 Example of Procedure for Setting Interrupt Skipping Function 2

(b) Example of Interrupt Skipping Function 2 Operation

Figure 16.89 shows an example of interrupt skipping 2 operation.

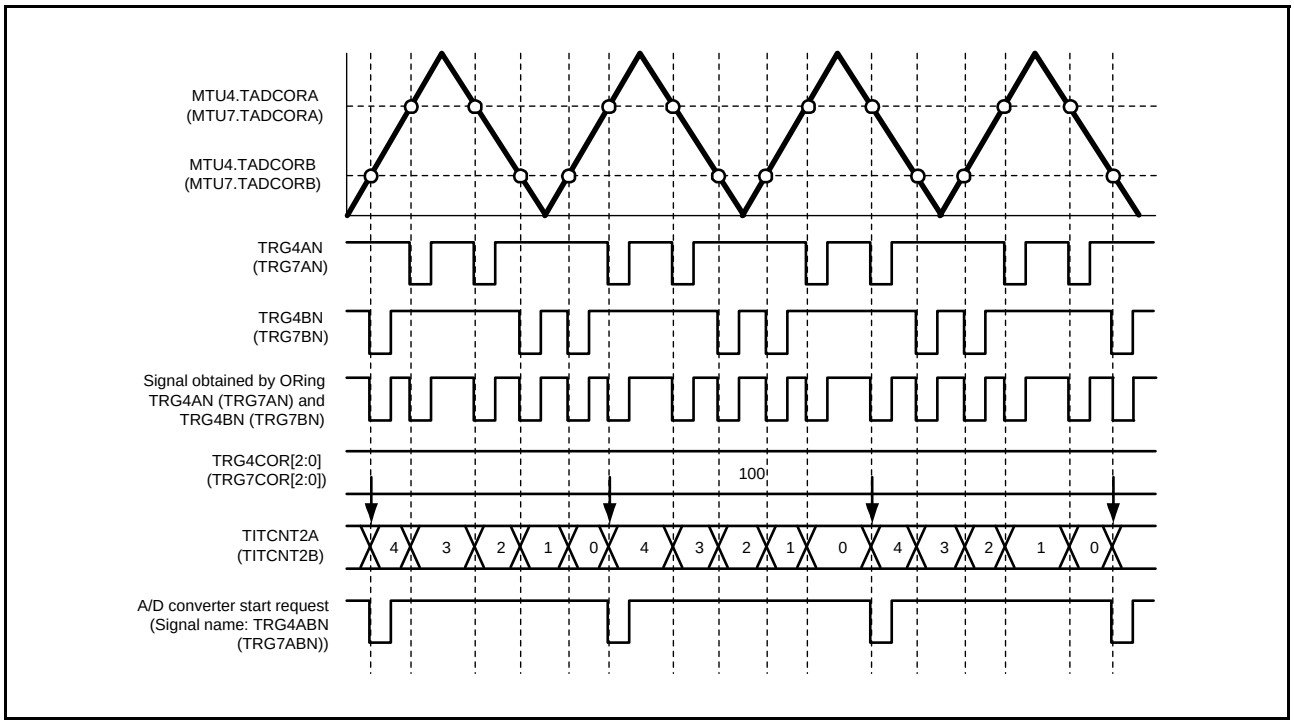


Figure 16.89 Example of Interrupt Skipping 2 Operation (Skipping Count is Set to Four)

16.3.10 Synchronous Operation of MTU0 to MTU4, and MTU6 and MTU7

(1) Synchronous Counter Start for MTU0 to MTU4, and MTU6 and MTU7

The counters in channels MTU0 to MTU4, and MTU6 and MTU7 can be started synchronously by making the TCSYSTR settings.

(a) Example of Procedure for Setting Synchronous Counter Start for MTU0 to MTU4, and MTU6 and MTU7

Figure 16.90 shows an example of synchronous counter start setting procedure.

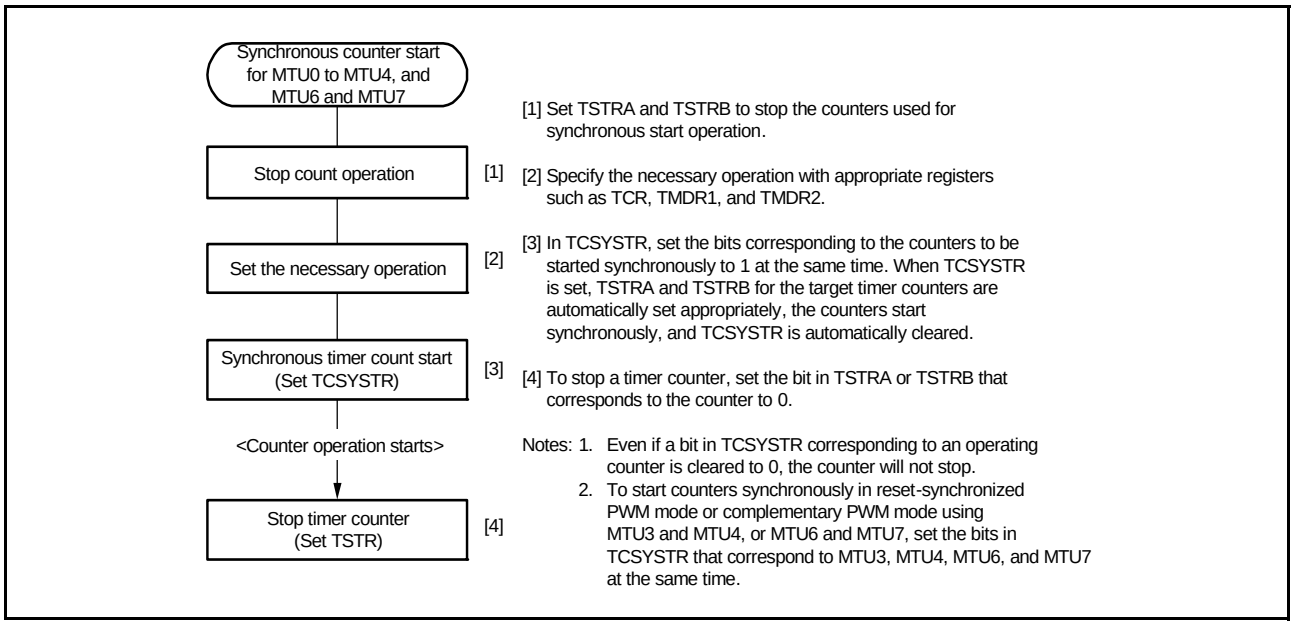


Figure 16.90 Example of Synchronous Counter Start Setting Procedure

(b) Examples of Synchronous Counter Start Operation

Figure 16.91 shows an example of synchronous counter start operation for MTU0 to MTU4, and MTU6 and MTU7.

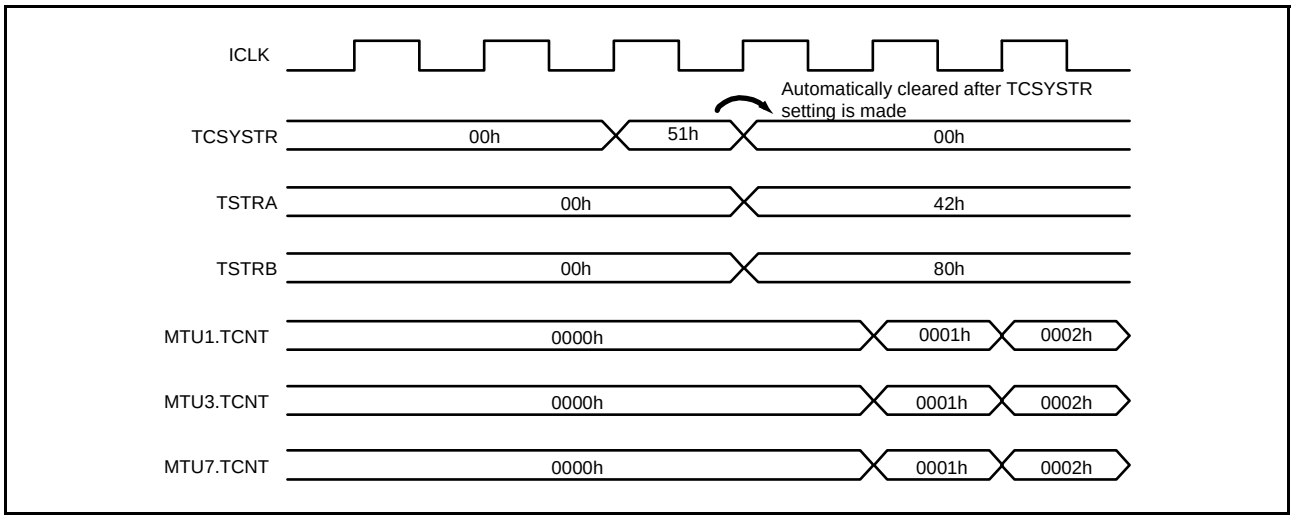


Figure 16.91 Example of Synchronous Counter Start Operation

(2) Clearing Counters of MTU6 and MTU7 by Flag Setting Sources (Synchronous Counter Clearing for MTU6 and MTU7)

The counters in MTU6 and MTU7 can be cleared by sources for setting the flags in MTU0.TSR to MTU2.TSR through the TSYCR setting.

(a) Example of Procedure for Specifying Counter Clearing for MTU6 and MTU7 by Flag Setting Sources

Figure 16.92 shows an example of procedure for specifying counter clearing for MTU6 and MTU7 by flag setting sources.

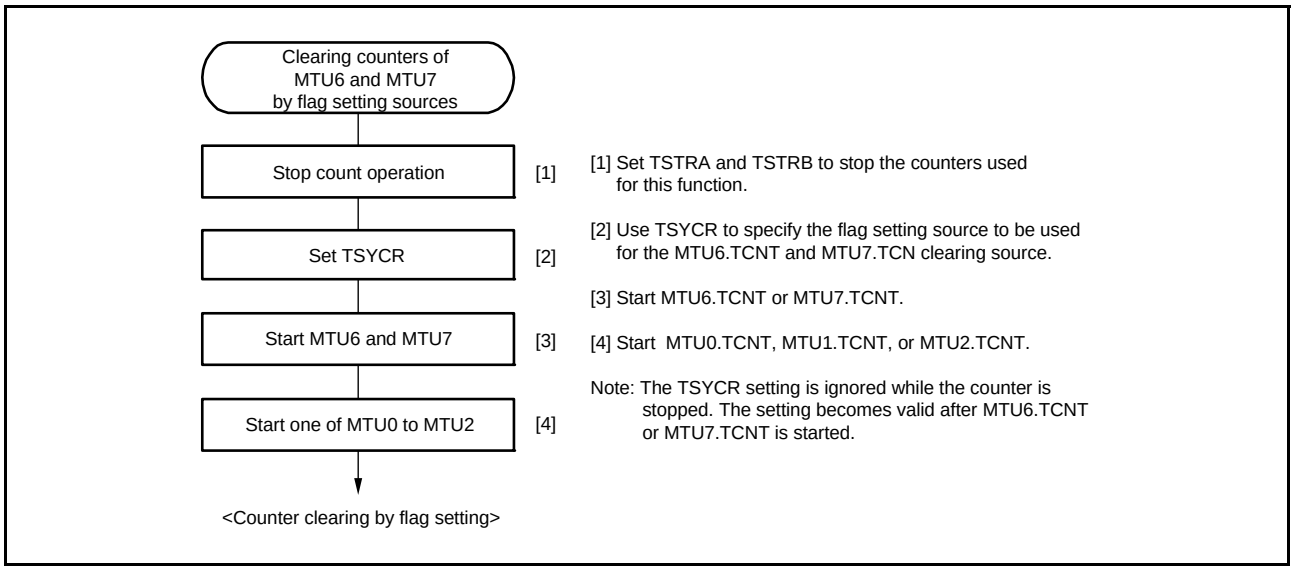


Figure 16.92 Example of Procedure for Specifying Counter Clearing for MTU6 and MTU7 by Flag Setting Sources

(b) Examples of Counter Clearing for MTU6 and MTU7 by Flag Setting Sources

Figure 16.93 and Figure 16.94 show examples of counter clearing for MTU6 and MTU7 by flag setting sources.

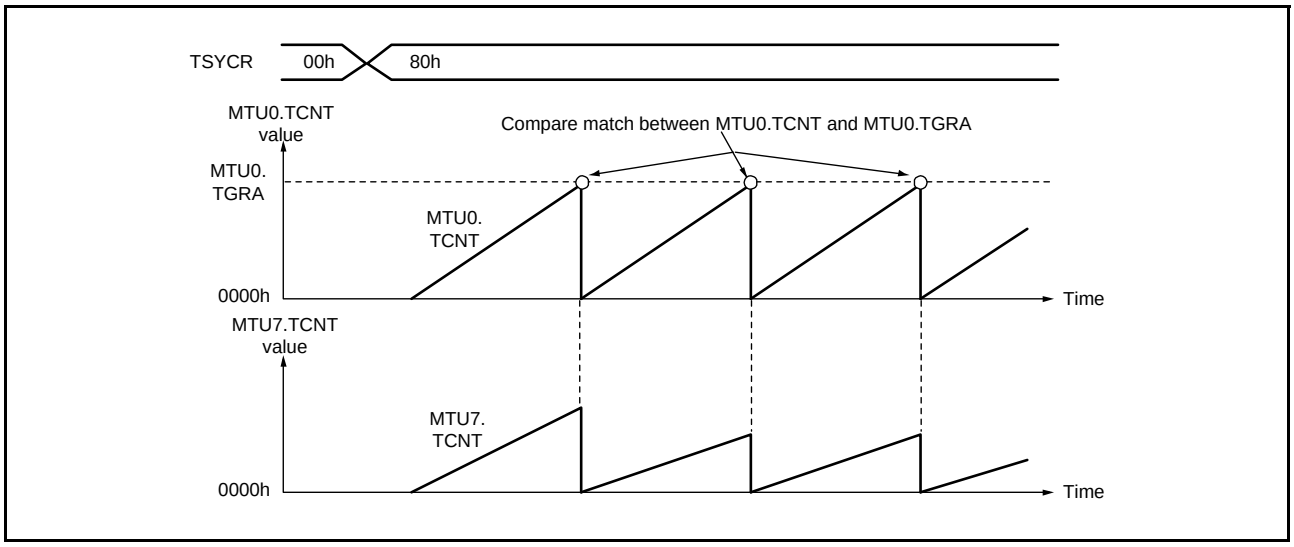


Figure 16.93 Example of Counter Clearing for MTU6 and MTU7 by Flag Setting Sources (1)

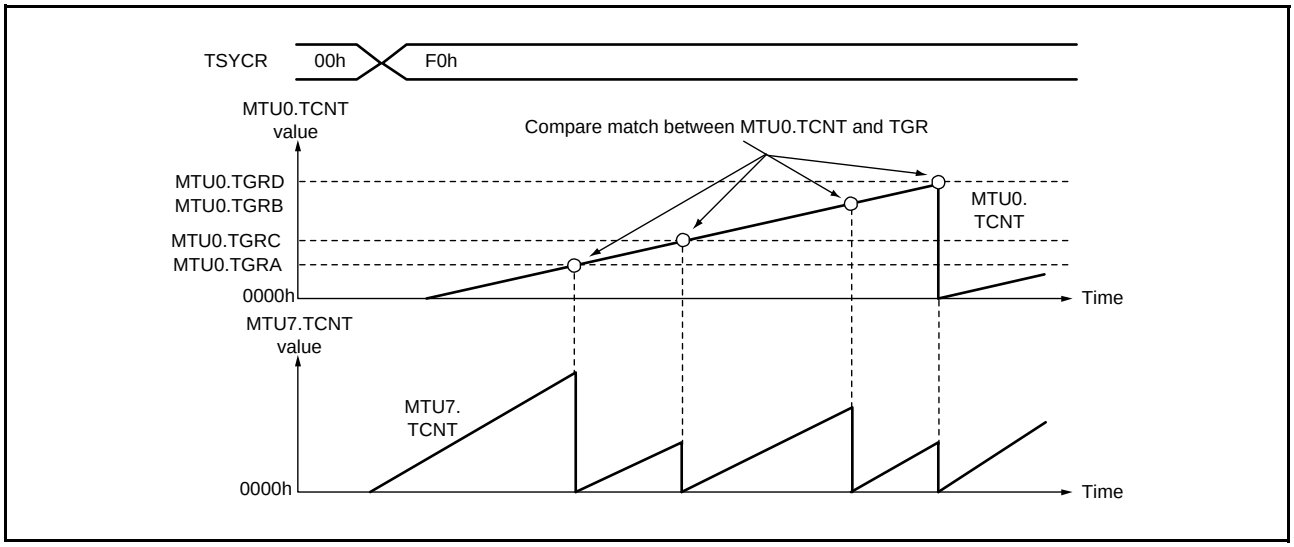


Figure 16.94 Example of Counter Clearing for MTU6 and MTU7 by Flag Setting Sources (2)

16.3.11 External Pulse Width Measurement

The pulse widths of up to three external input lines can be measured in MTU5.

(1) Example of External Pulse Width Measurement Setting Procedure

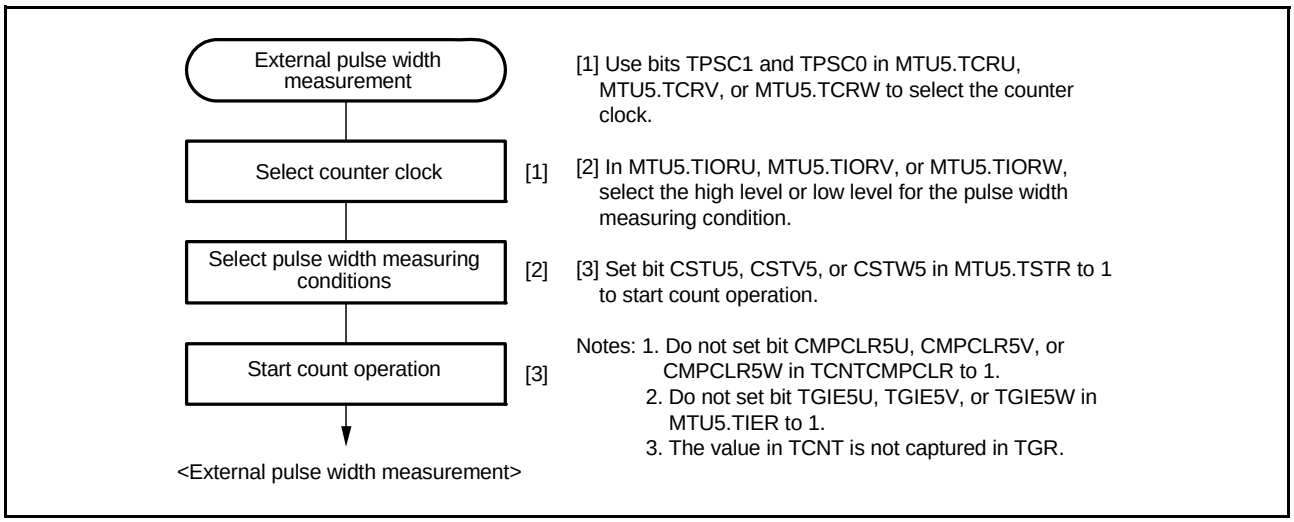


Figure 16.95 Example of External Pulse Width Measurement Setting Procedure

(2) Example of External Pulse Width Measurement

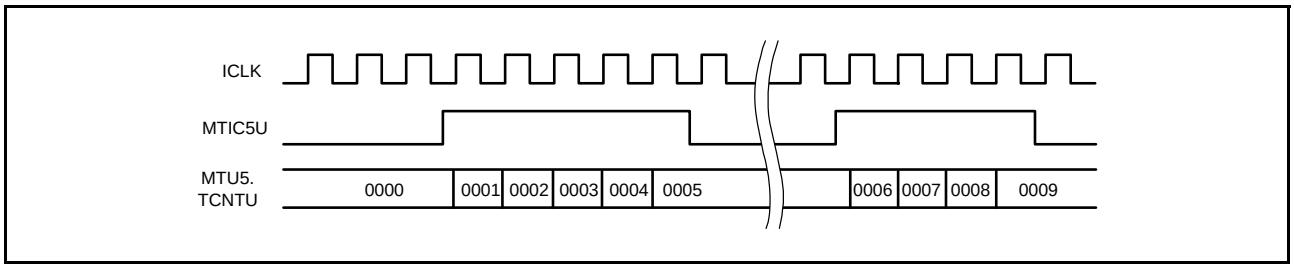


Figure 16.96 Example of External Pulse Width Measurement (Measuring High Pulse Width)

16.3.12 Dead Time Compensation

By measuring the delay of the output waveform and reflecting it to duty ratio, the external pulse width measurement function can be used as the dead time compensation function while the complementary PWM is in operation.

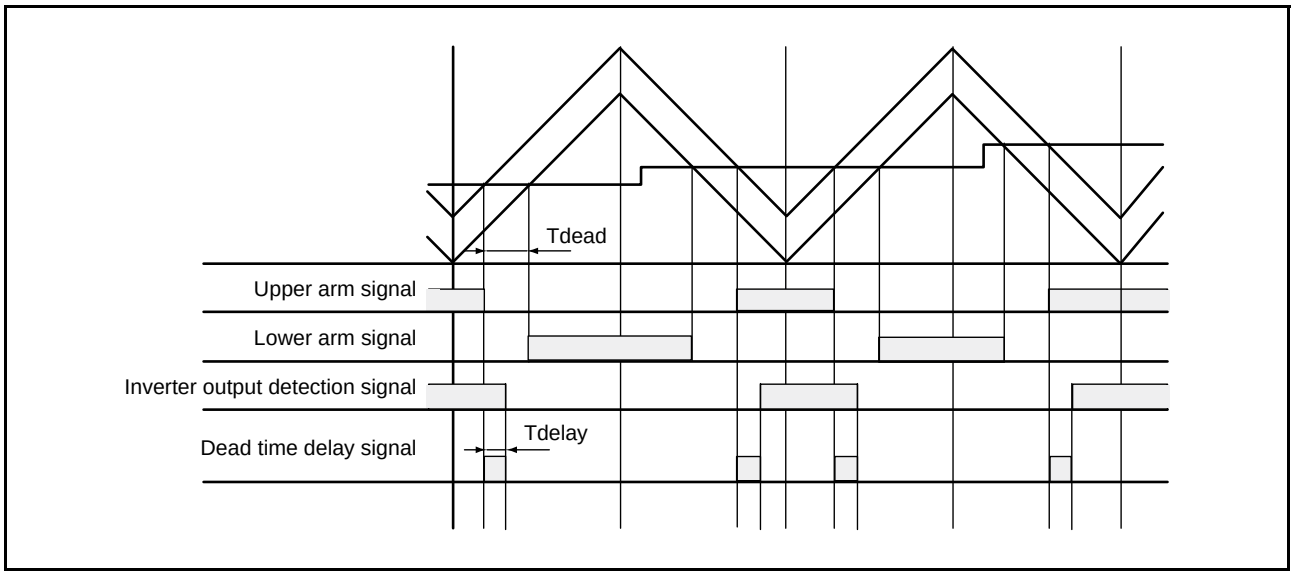


Figure 16.97 Delay in Dead Time in Complementary PWM Operation

(1) Example of Dead Time Compensation Setting Procedure

Figure 16.98 shows an example of dead time compensation setting procedure by using three counters in MTU5.

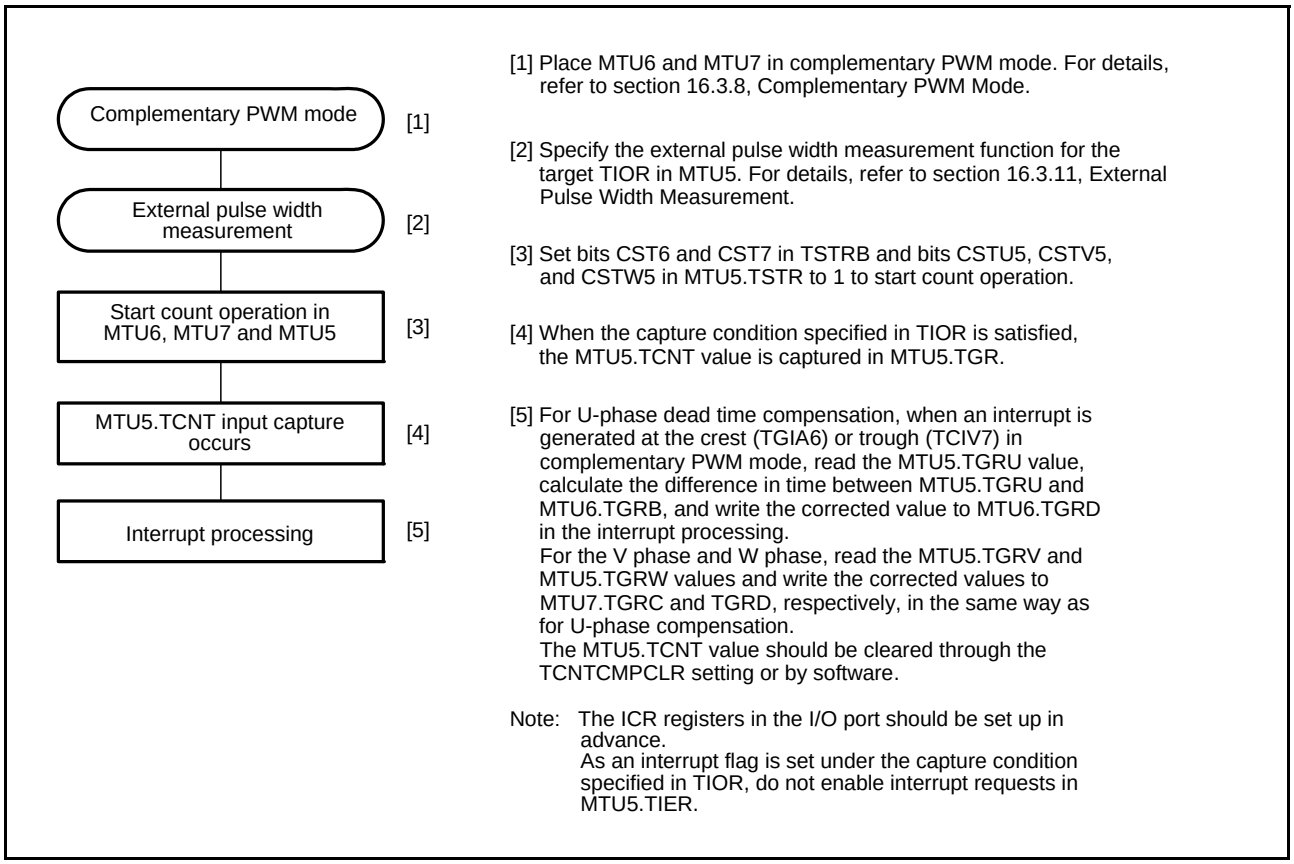


Figure 16.98 Example of Dead Time Compensation Setting Procedure

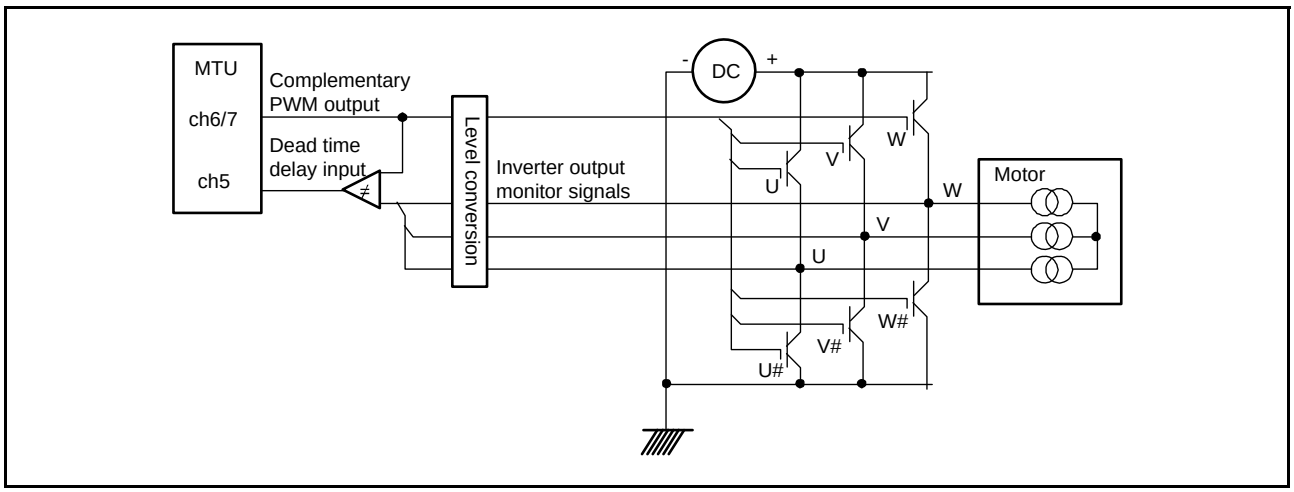


Figure 16.99 Example of Motor Control Circuit Configuration

16.3.13 TCNT Capture at Crest and/or Trough in Complementary PWM Operation

The TCNT value is captured in TGR at either the crest or trough or at both the crest and trough during complementary PWM operation. The timing for capturing in TGR can be selected by TIOR.

Figure 16.100 is an operating example in which TCNT is used as a free-running counter without being cleared, and the TCNT value is captured in TGR at the specified timing (either crest or trough, or both crest and trough).

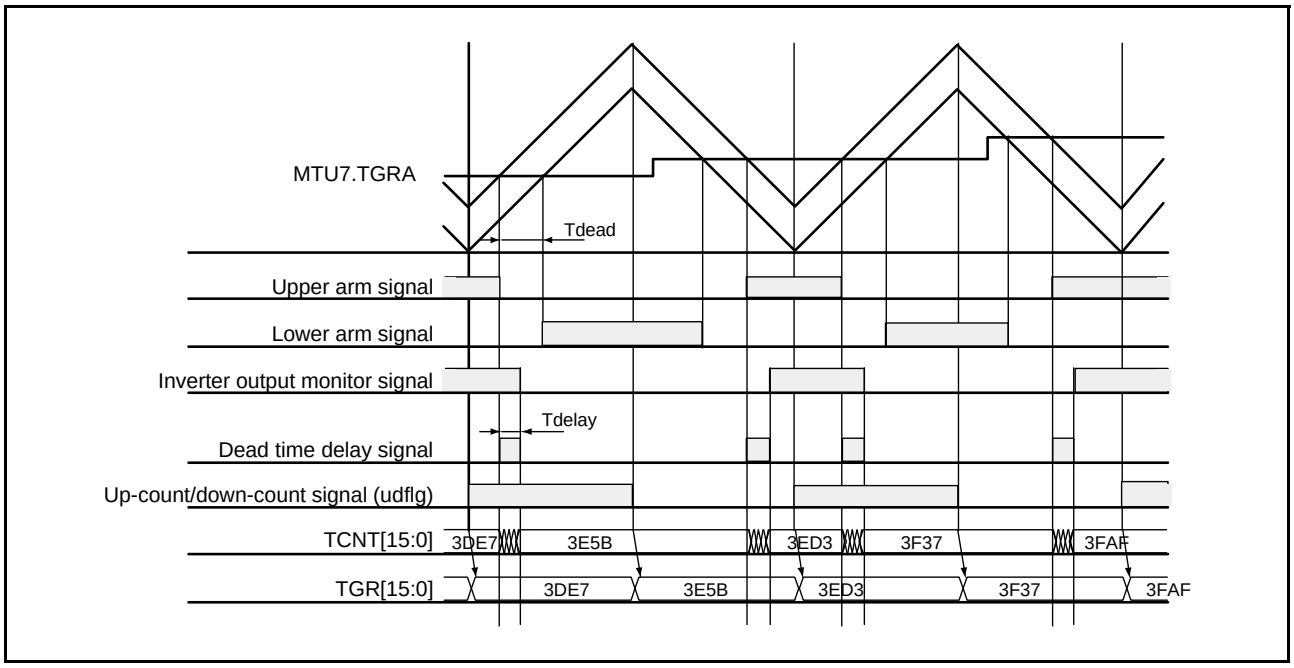


Figure 16.100 TCNT Capture at Crest and/or Trough in Complementary PWM Operation

16.4 Interrupt Sources

16.4.1 Interrupt Sources and Priorities

There are three kinds of MTU3 interrupt source; TGR input capture/compare match, TCNT overflow, and TCNT underflow. Each interrupt source has its own status flag and enable/disable bit, allowing the generation of interrupt request signals to be enabled or disabled individually.

When an interrupt source is detected, the corresponding status flag in TSR is set to 1. If the corresponding enable/disable bit in TIER is set to 1 at this time, an interrupt is requested. Setting the status flag to 1 cancels the interrupt request. However, if a further interrupt is generated while the corresponding status flag is 1, the interrupt will be ignored. To enable the acceptance of an interrupt, the flag of the interrupt generation source should be 0.

Relative channel priorities can be changed by the interrupt controller; however the priority within a channel is fixed. For details, see section 11, Interrupt Controller (ICU).

Table 16.73 lists the MTU3 interrupt sources.

Table 16.73 MTU3 Interrupt Sources

Channel	Name	Interrupt Source	DTC Activation	Priority
MTU0	TGIA0	MTU0.TGRA input capture/compare match	Possible	High
	TGIB0	MTU0.TGRB input capture/compare match	Possible	
	TGIC0	MTU0.TGRC input capture/compare match	Possible	
	TGID0	MTU0.TGRD input capture/compare match	Possible	
	TCIV0	MTU0.TCNT overflow	Not possible	
	TGIE0	MTU0.TGRE compare match	Not possible	
	TGIF0	MTU0.TGRF compare match	Not possible	
MTU1	TGIA1	MTU1.TGRA input capture/compare match	Possible	
	TGIB1	MTU1.TGRB input capture/compare match	Possible	
	TCIV1	MTU1.TCNT overflow	Not possible	
	TCIU1	MTU1.TCNT underflow	Not possible	
MTU2	TGIA2	MTU2.TGRA input capture/compare match	Possible	
	TGIB2	MTU2.TGRB input capture/compare match	Possible	
	TCIV2	MTU2.TCNT overflow	Not possible	
	TCIU2	MTU2.TCNT underflow	Not possible	
MTU3	TGIA3	MTU3.TGRA input capture/compare match	Possible	
	TGIB3	MTU3.TGRB input capture/compare match	Possible	
	TGIC3	MTU3.TGRC input capture/compare match	Possible	
	TGID3	MTU3.TGRD input capture/compare match	Possible	
	TCIV3	MTU3.TCNT overflow	Not possible	
MTU4	TGIA4	MTU4.TGRA input capture/compare match	Possible	
	TGIB4	MTU4.TGRB input capture/compare match	Possible	
	TGIC4	MTU4.TGRC input capture/compare match	Possible	
	TGID4	MTU4.TGRD input capture/compare match	Possible	
	TCIV4	MTU4.TCNT overflow/underflow (only in complementary PWM mode)	Possible	
MTU5	TGIU5	MTU5.TGRU input capture/compare match	Possible	
	TGIV5	MTU5.TGRV input capture/compare match	Possible	
	TGIW5	MTU5.TGRW input capture/compare match	Possible	
MTU6	TGIA6	MTU6.TGRA input capture/compare match	Possible	
	TGIB6	MTU6.TGRB input capture/compare match	Possible	
	TGIC6	MTU6.TGRC input capture/compare match	Possible	
	TGID6	MTU6.TGRD input capture/compare match	Possible	
	TCIV6	MTU6.TCNT overflow	Not possible	
MTU7	TGIA7	MTU7.TGRA input capture/compare match	Possible	
	TGIB7	MTU7.TGRB input capture/compare match	Possible	
	TGIC7	MTU7.TGRC input capture/compare match	Possible	
	TGID7	MTU7.TGRD input capture/compare match	Possible	
	TCIV7	MTU7.TCNT overflow/underflow (only in complementary PWM mode)	Possible	Low

Note 1. This table shows the initial state immediately after a reset. The relative channel priorities can be changed by the interrupt controller.

(1) Input Capture/Compare Match Interrupt

An interrupt is requested if the TGIE bit in TIER is set to 1 when a TGR input capture/compare match occurs on a channel and the TGE flag in TSR is set to 1. Clearing the TGE flag to 0 cancels the interrupt request. The MTU3 has 29 input capture/compare match interrupts (six for MTU0, four each for MTU3, MTU4, MTU6, and MTU7, two each for MTU1 and MTU2, and three for MTU5). The MTU0.TGFE and MTU0.TGFF_0 flags in MTU0 are not set by the occurrence of an input capture.

(2) Overflow Interrupt

An interrupt is requested if the TCIEV bit in TIER is set to 1 when a TCNT overflow occurs on a channel and the TCFV flag in TSR is set to 1. Clearing the TCFV flag to 0 cancels the interrupt request. The MTU3 has seven overflow interrupts (one for each channel).
Furthermore, when operation is in complementary PWM mode, an underflow of MTU4.TCNT and MTU7_4.TCNT leads to setting of the TCVF flag.

(3) Underflow Interrupt

An interrupt is requested if the TCIEU bit in TIER is set to 1 when a TCNT underflow occurs on a channel and the TCFU flag in TSR is set to 1. Clearing the TCFU flag to 0 cancels the interrupt request. The MTU3 has two underflow interrupts (one each for MTU1 and MTU2).

16.4.2 DTC Activation

The DTC can be activated by the TGR input capture/compare match interrupt in each channel or the overflow interrupt in MTU4 and MTU7. For details, see section 14, Data Transfer Controller (DTC).
The MTU3 provides a total of 29 input capture/compare match interrupts and overflow interrupts that can be used as DTC activation sources: four each for MTU0, MTU3, and MTU6, two each for MTU1 and MTU2, five each for MTU4 and MTU7, and three for MTU5.
However, as similar to the interrupt handling, if a further DTC activation request is generated while the corresponding status flag is 1, the interrupt will be ignored. To enable the acceptance of an interrupt, the flag of the interrupt generation source should be 0.

16.4.3 A/D Converter Activation

The A/D converter can be activated by one of the following three methods in the MTU3. Table 16.73 shows the relationship between interrupt sources and A/D converter start request signals.

(1) A/D Converter Activation by TGRA Input Capture/Compare Match or at MTU4.TCNT (MTU7.TCNT) Trough in Complementary PWM Mode

The A/D converter can be activated by the occurrence of a TGRA input capture/compare match in each channel. In addition, if complementary PWM operation is performed while the TTGE2 bit in MTU4.TIER (MTU7.TIER) is set to 1, the A/D converter can be activated at the trough of MTU4.TCNT (MTU7.TCNT) count (MTU4.TCNT (MTU7.TCNT) = 0000h).
A/D converter start request signal TRGAnN is issued to the A/D converter under either of the following conditions (n = MTU0 to MTU4, MTU6, or MTU7).

- When a TGRA input capture/compare match occurs on a channel and the TGFA flag in TSR is set to 1 while the TTGE bit in TIER is set to 1
- When the MTU4.TCNT (MTU7.TCNT) count reaches the trough (MTU4.TCNT (MTU7.TCNT) = 0000h) during complementary PWM operation while the TTGE2 bit in MTU4.TIER (MTU7.TIER) is set to 1

When either condition is satisfied, if A/D converter start signal TRGAnN from the MTU3 is selected as the trigger in the A/D converter, A/D conversion will start.

(2) A/D Converter Activation by Compare Match between MTU0.TCNT and MTU0.TGRE

A/D converter start request signal TRG0N is issued to the A/D converter when a compare match occurs between MTU0.TCNT and MTU0.TGRE in MTU0.
When the TGFE flag in MTU0.TSR2 is set to 1 by the occurrence of a compare match between MTU0.TCNT and MTU0.TGRE in MTU0 while the TTGE2 bit in MTU0.TIER2 is set to 1, A/D converter start request TGR0N is issued to the A/D converter. If A/D converter start signal TRG0N from the MTU3 is selected as the trigger in the A/D converter, A/D conversion will start.

(3) A/D Converter Activation by A/D Converter Start Request Delaying Function

The A/D converter can be activated by generating A/D converter start request signal TRG4AN or TRG4BN (TRG7AN or TRG7BN) when the MTU4.TCNT (MTU7.TCNT) count matches the MTU4.TADCORA or MTU4.TADCORB (MTU7.TADCORA or MTU7.TADCORB) value if the UT4AE, DT4AE, UT4BE, or DT4BE (UT7AE, DT7AE, UT7BE, or DT7BE) bit in the A/D converter start request control register (MTU4.TADCR (MTU7.TADCR)) is set to 1. For details, refer to section 16.3.9, A/D Converter Start Request Delaying Function.
A/D conversion will start when TRG4AN (TRG7AN) is generated if A/D converter start signal TRG4AN (TRG7AN) from the MTU3 is selected as the trigger in the A/D converter, when TRG4BN (TRG7BN) is generated if TRG4BN (TRG7BN) from the MTU3 is selected as the trigger in the A/D converter, or when TRG4ABN (TRG7ABN) is generated if TRG4ABN (TRG7ABN) from the MTU3 is selected as the trigger in the A/D converter.

Table 16.74 Interrupt Sources and A/D Converter Start Request Signals

Target Registers	Interrupt Source	A/D Converter Start Request Signal
MTU0.TGRA and MTU0.TCNT	Input capture/compare match	TRGA0N
MTU1.TGRA and MTU1.TCNT		TRGA1N
MTU2.TGRA and MTU2.TCNT		TRGA2N
MTU3.TGRA and MTU3.TCNT		TRGA3N
MTU4.TGRA and MTU4.TCNT*1		TRGA4N
MTU4.TCNT	MTU4.TCNT trough in complementary PWM mode	
MTU6.TGRA and MTU6.TCNT	Input capture/compare match	TRGA6N
MTU7.TGRA and MTU7.TCNT*1		TRGA7N
MTU7.TCNT	MTU7.TCNT trough in complementary PWM mode	
MTU0.TGRE and MTU0.TCNT	Compare match	TRG0AN
MTU4.TADCORA and MTU4.TCNT	Compare match	TRG4AN
MTU4.TADCORB and MTU4.TCNT		TRG4BN
MTU7.TADCORA and MTU7.TCNT		TRG7AN
MTU7.TADCORB and MTU7.TCNT		TRG7BN
MTU4.TADCORA and MTU4.TCNT, MTU4.TADCORB and MTU4.TCNT	Compare match (interrupt skipping function 2)	TRG4ABN
MTU7.TADCORA and MTU7.TCNT, MTU7.TADCORB and MTU7.TCNT		TRG7ABN

Note 1. Since PWM waveforms are generated in complementary PWM mode, MTU4.TGRA (MTU7.TGRA) compare match not only with MTU4.TCNT (MTU7.TCNT) but also with MTU3.TCNT (MTU6.TCNT) and TCNTSA (TCNTSB) is detected. Accordingly, when compare match with MTU3.TCNT (MTU6.TCNT) and TCNTSA (TCNTSB) occurs, TRGA4N (TRGA7N) is also generated. When MTU3 and MTU4 (MTU6 and MTU7) are made to operate in complementary PWM mode for generating an A/D converter start request, use the A/D converter start request by compare match between MTU4.TCNT (MTU7.TCNT) and MTU4.TADCORA/B (MTU7.TADCORA/B).

16.5 Operation Timing

16.5.1 Input/Output Timing

(1) TCNT Count Timing

Figure 16.101 and Figure 16.102 show the TCNT count timing in internal clock operation, Figure 16.103 shows the TCNT count timing in external clock operation (normal mode), and Figure 16.104 shows the TCNT count timing in external clock operation (phase counting mode).

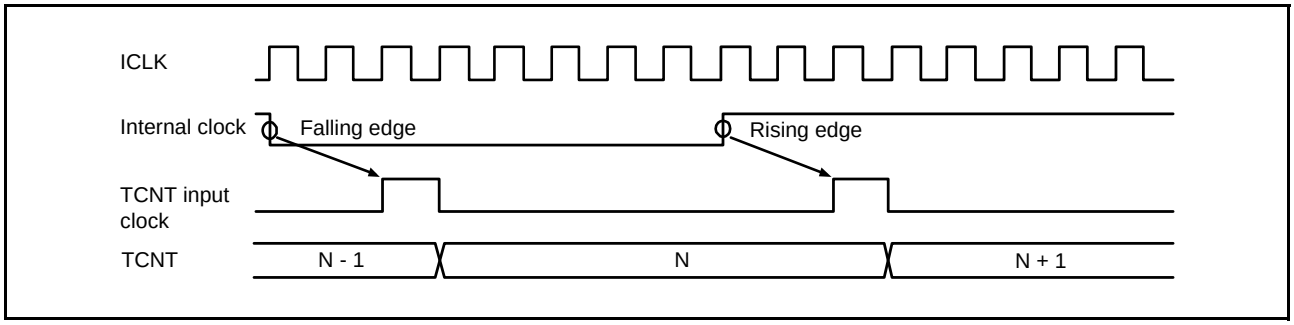


Figure 16.101 Count Timing in Internal Clock Operation (MTU0 to MTU4, MTU6, and MTU7)

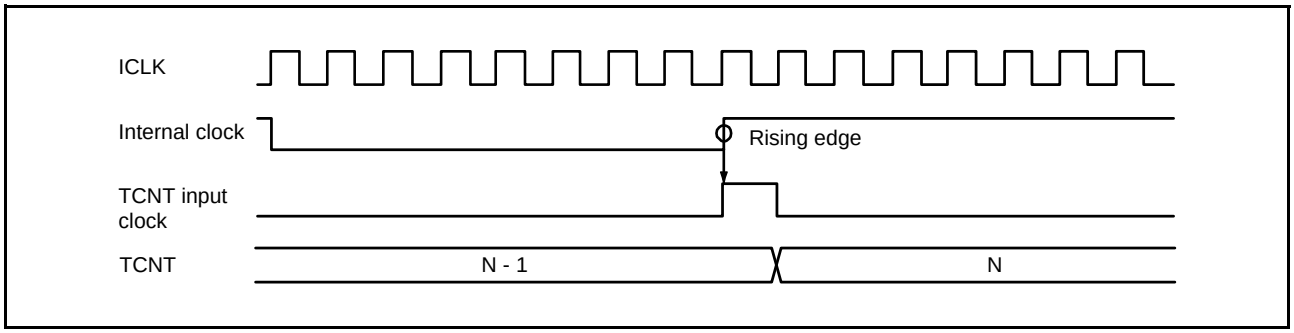


Figure 16.102 Count Timing in Internal Clock Operation (MTU5)

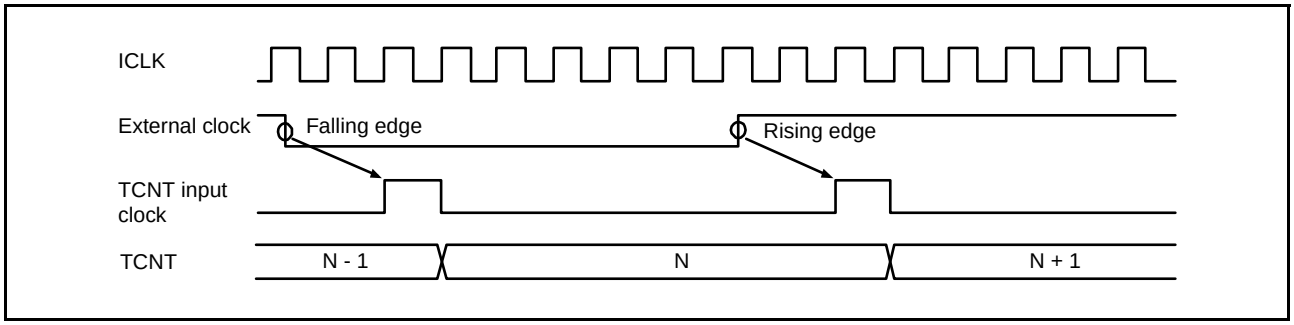


Figure 16.103 Count Timing in External Clock Operation (MTU0 to MTU4)

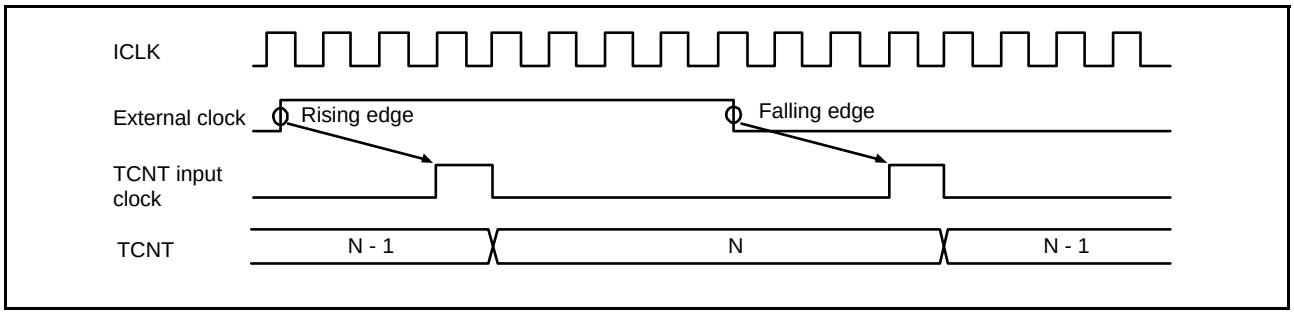


Figure 16.104 Count Timing in External Clock Operation (Phase Counting Mode)

(2) Output Compare Output Timing

A compare match signal is generated in the final state in which TCNT and TGR match (the point at which the count value matched by TCNT is updated). When a compare match signal is generated, the value set in TIOR is output from the output compare output pin (MTIOC pin). After a match between TCNT and TGR, the compare match signal is not generated until the TCNT input clock is generated.

Figure 16.105 shows the output compare output timing (normal mode or PWM mode) and Figure 16.106 shows the output compare output timing (complementary PWM mode or reset-synchronized PWM mode).

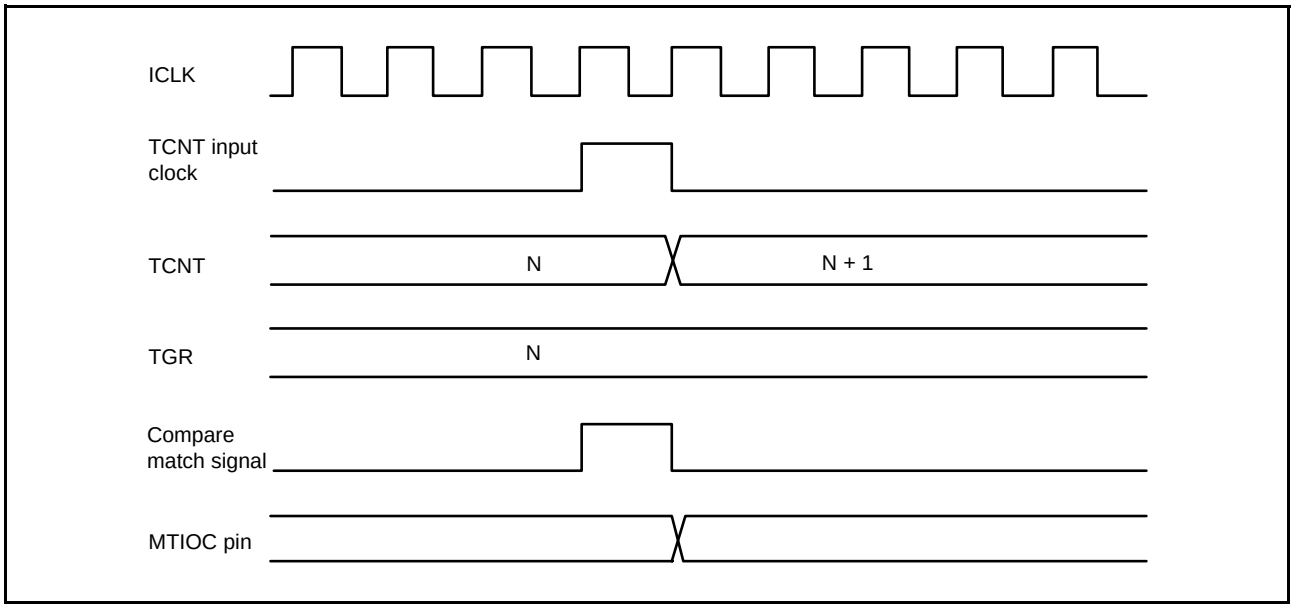


Figure 16.105 Output Compare Output Timing (Normal Mode or PWM Mode)

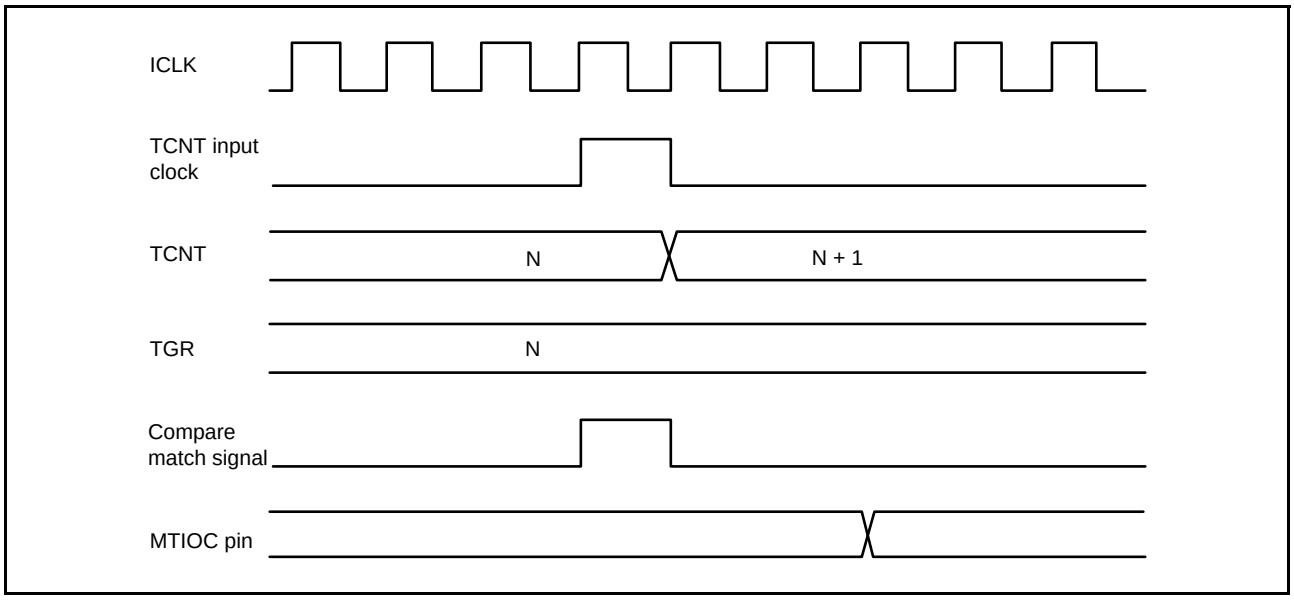


Figure 16.106 Output Compare Output Timing (Complementary PWM Mode or Reset-Synchronized PWM Mode)

(3) Input Capture Signal Timing

Figure 16.107 shows the input capture signal timing.

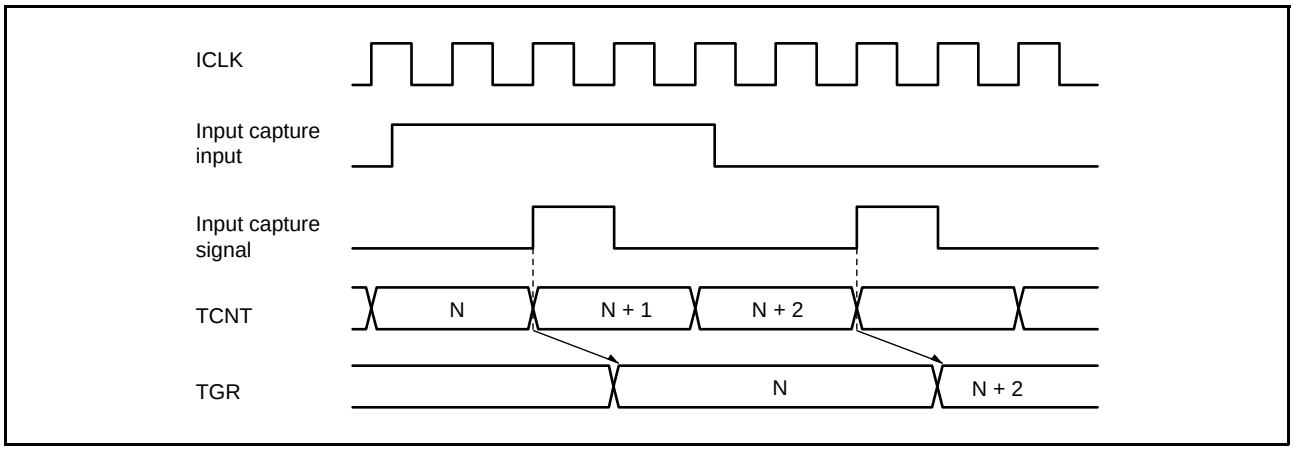


Figure 16.107 Input Capture Input Signal Timing

(4) Timing for Counter Clearing by Compare Match/Input Capture

FFigure 16.108 and Figure 16.109 show the timing when counter clearing on compare match is specified, and Figure 16.110 shows the timing when counter clearing on input capture is specified.

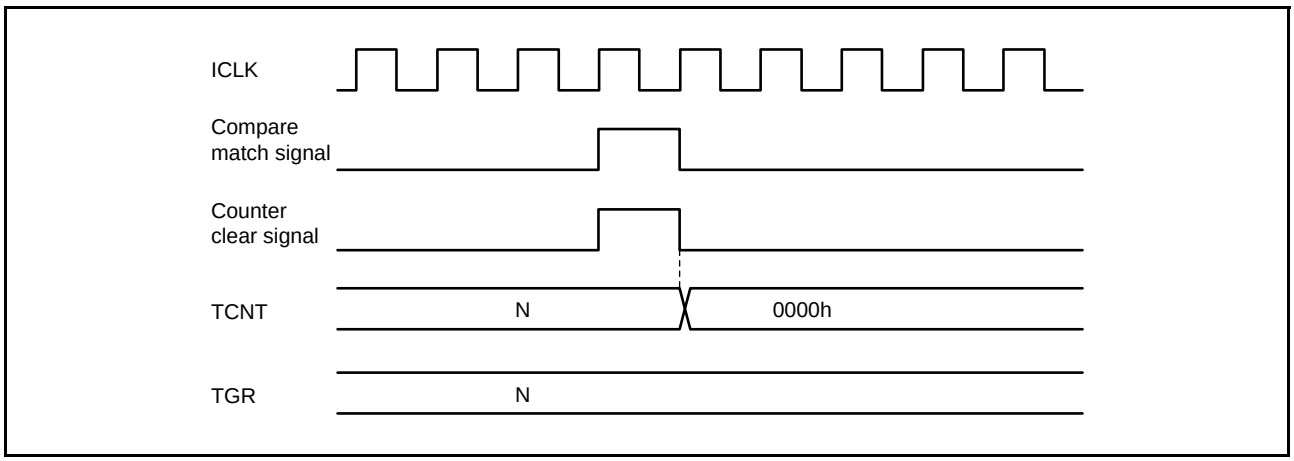


Figure 16.108 Counter Clear Timing (Compare Match) (MTU0 to MTU4, MTU6, and MTU7)

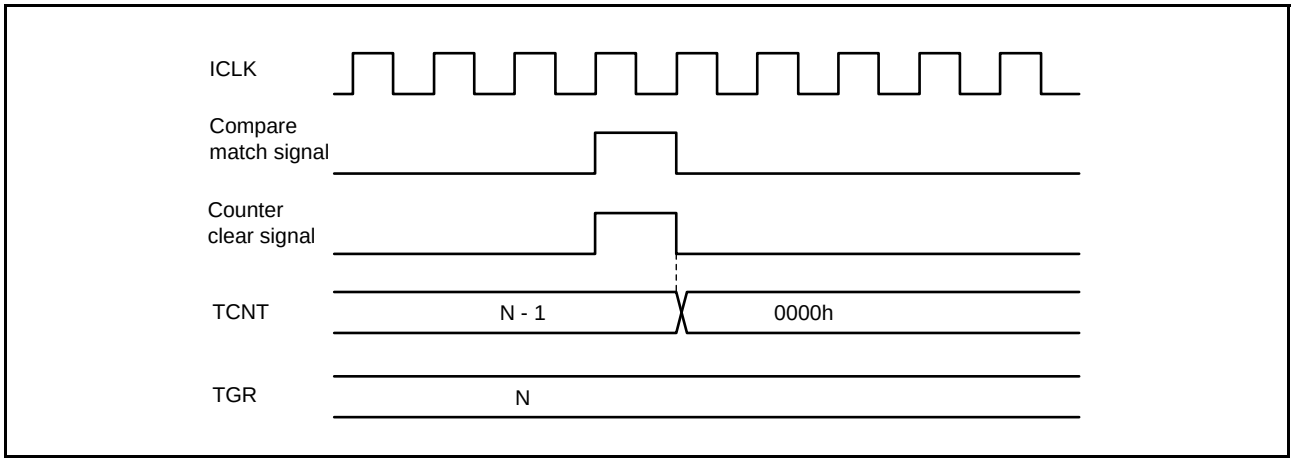


Figure 16.109 Counter Clear Timing (Compare Match) (MTU5)

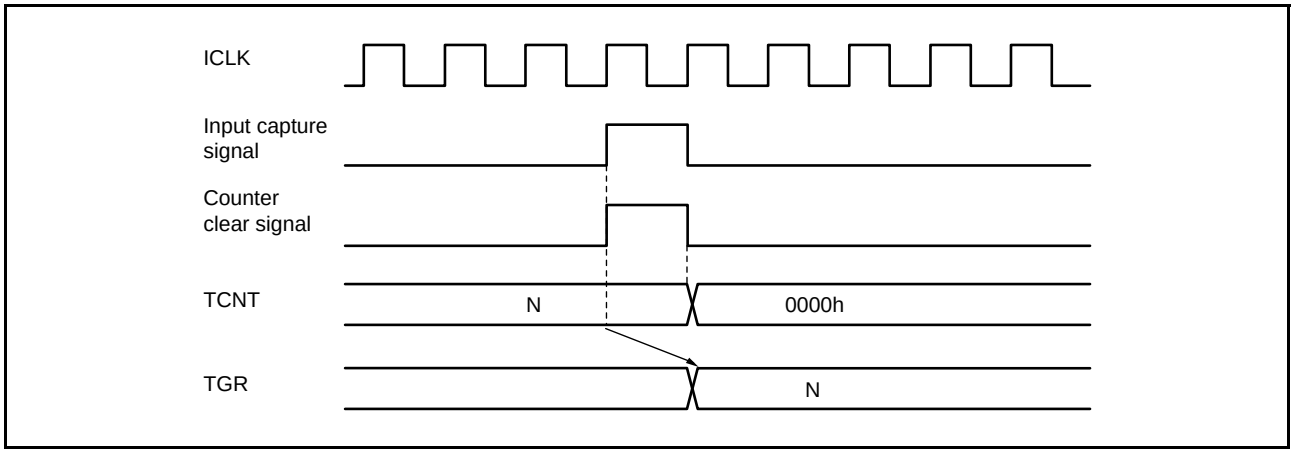


Figure 16.110 Counter Clear Timing (Input Capture) (MTU0 to MTU7)

(5) Buffer Operation Timing

Figure 16.111 to Figure 16.113 show the timing in buffer operation.

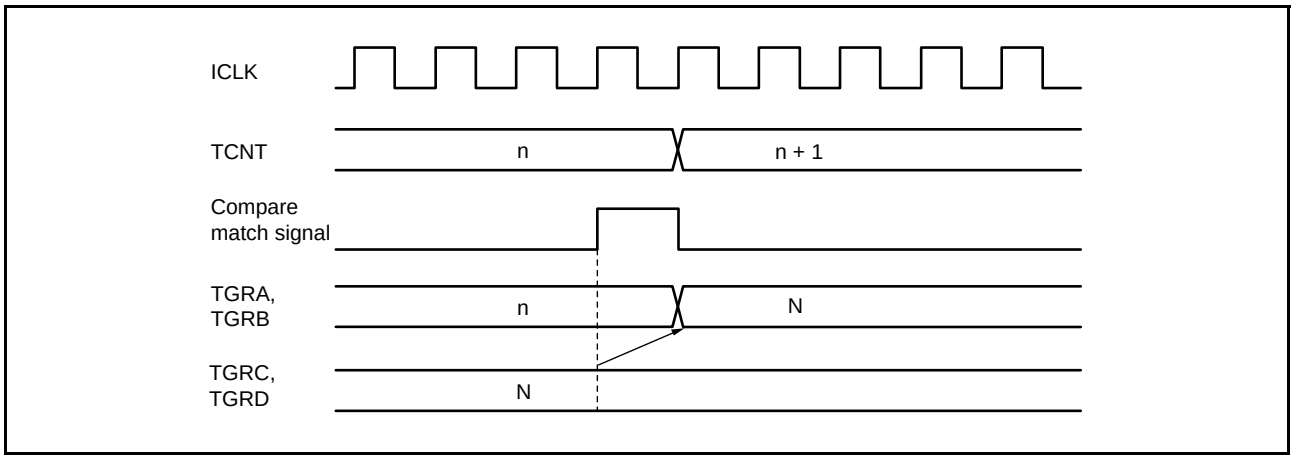


Figure 16.111 Buffer Operation Timing (Compare Match)

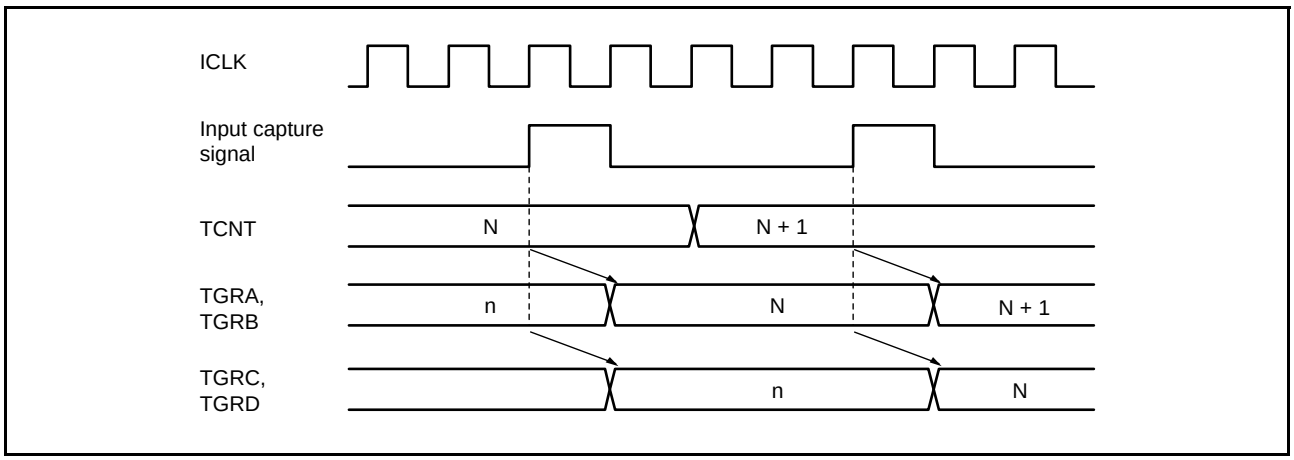


Figure 16.112 Buffer Operation Timing (Input Capture)

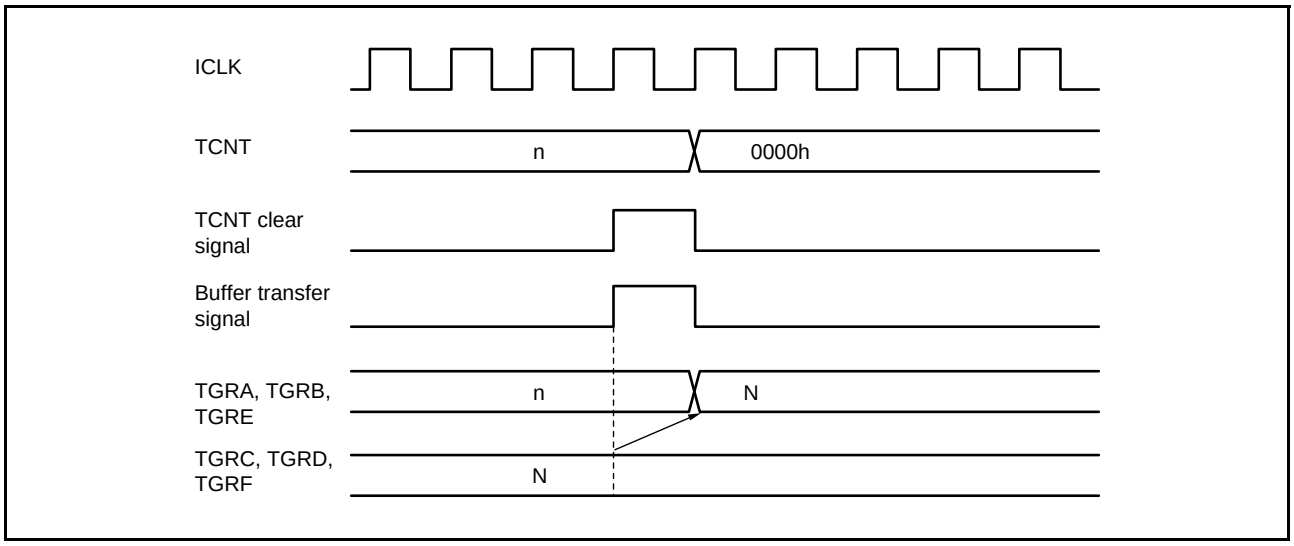


Figure 16.113 Buffer Operation Timing (when TCNT Cleared)

(6) Buffer Transfer Timing (Complementary PWM Mode)

Figure 16.114 to Figure 16.116 show the buffer transfer timing in complementary PWM mode.

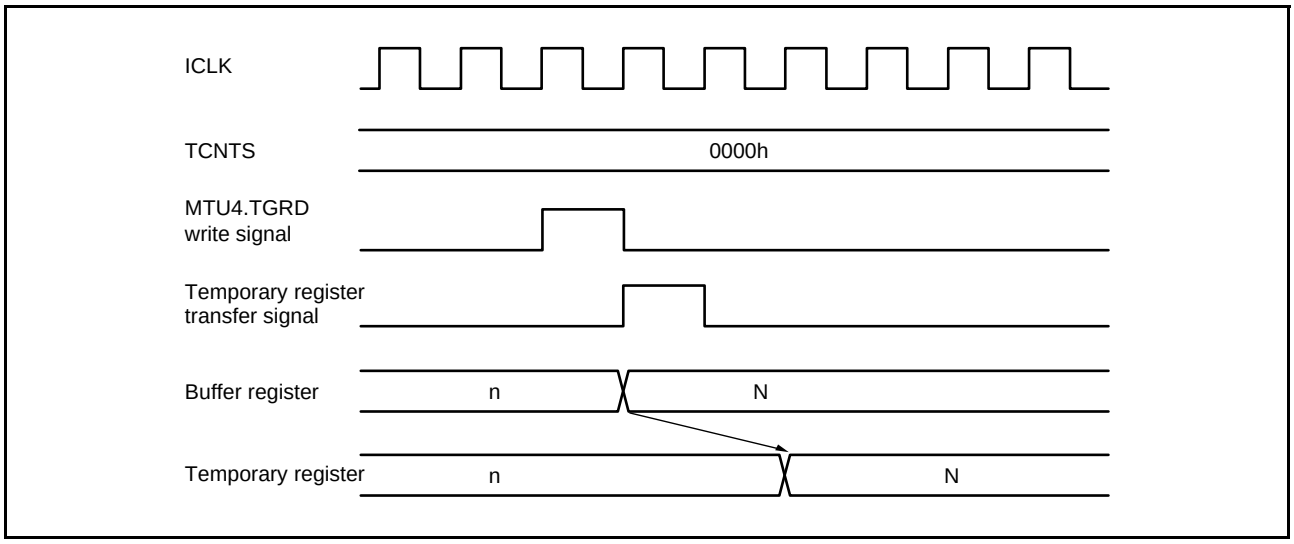


Figure 16.114 Transfer Timing from Buffer Register to Temporary Register (TCNTSA Stopped)

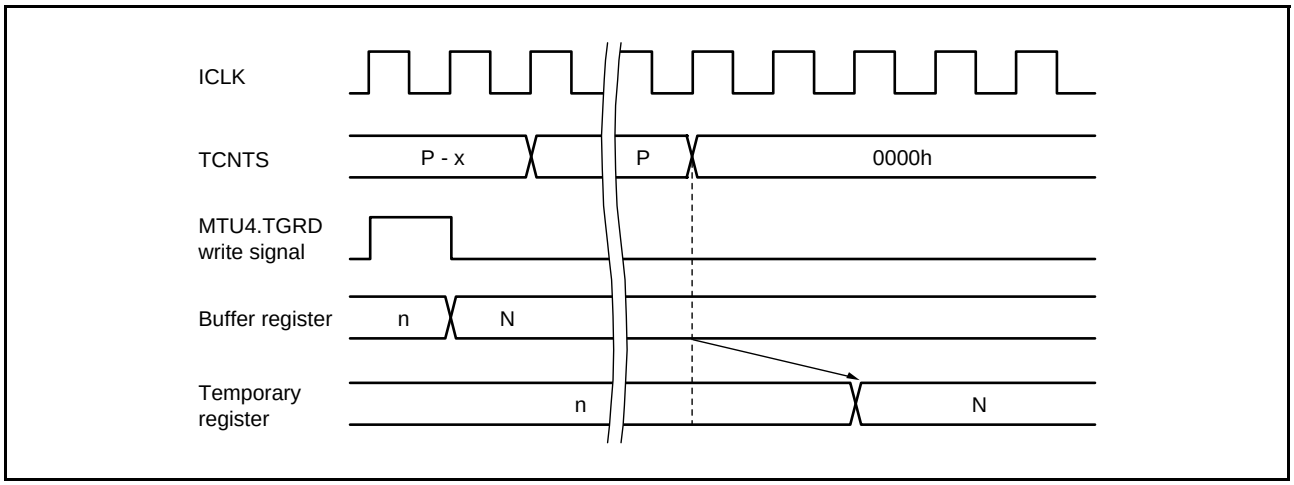


Figure 16.115 Transfer Timing from Buffer Register to Temporary Register (TCNTSA Operating)

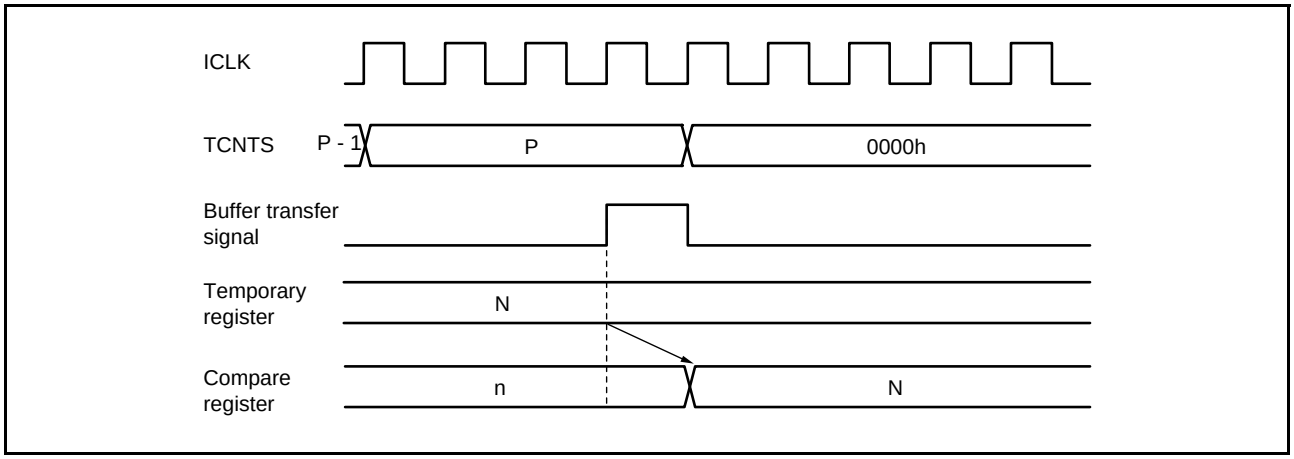


Figure 16.116 Transfer Timing from Temporary Register to Compare Register

16.5.2 Interrupt Signal Timing

(1) Timing for TGF Flag Setting by Compare Match

Figure 16.117 and Figure 16.118 show the timing of TGF flag setting in TSR on compare match and the TGI interrupt request signal timing.

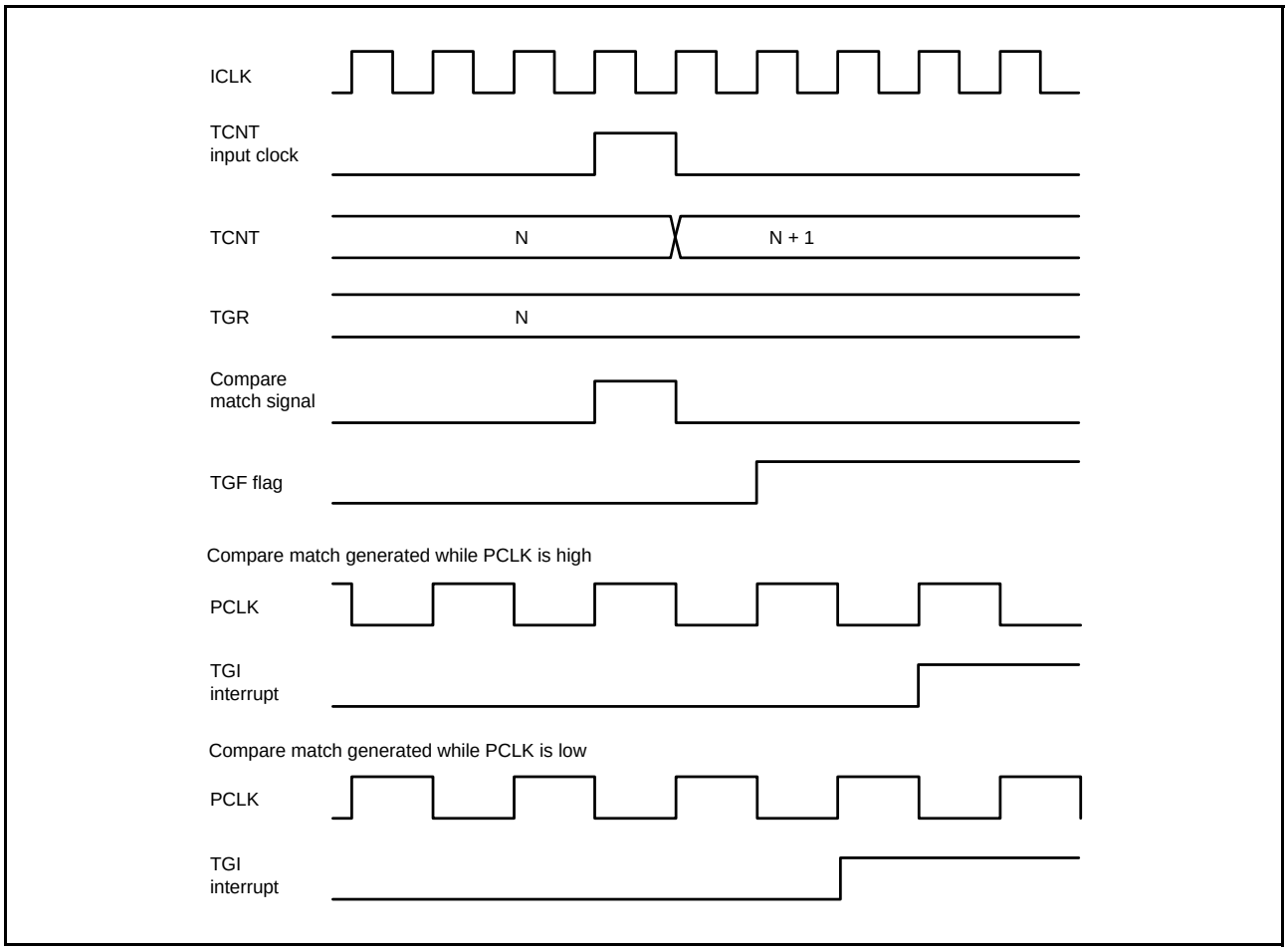


Figure 16.117 TGI Interrupt Timing (Compare Match) (MTU0 to MTU4, MTU6, and MTU7)

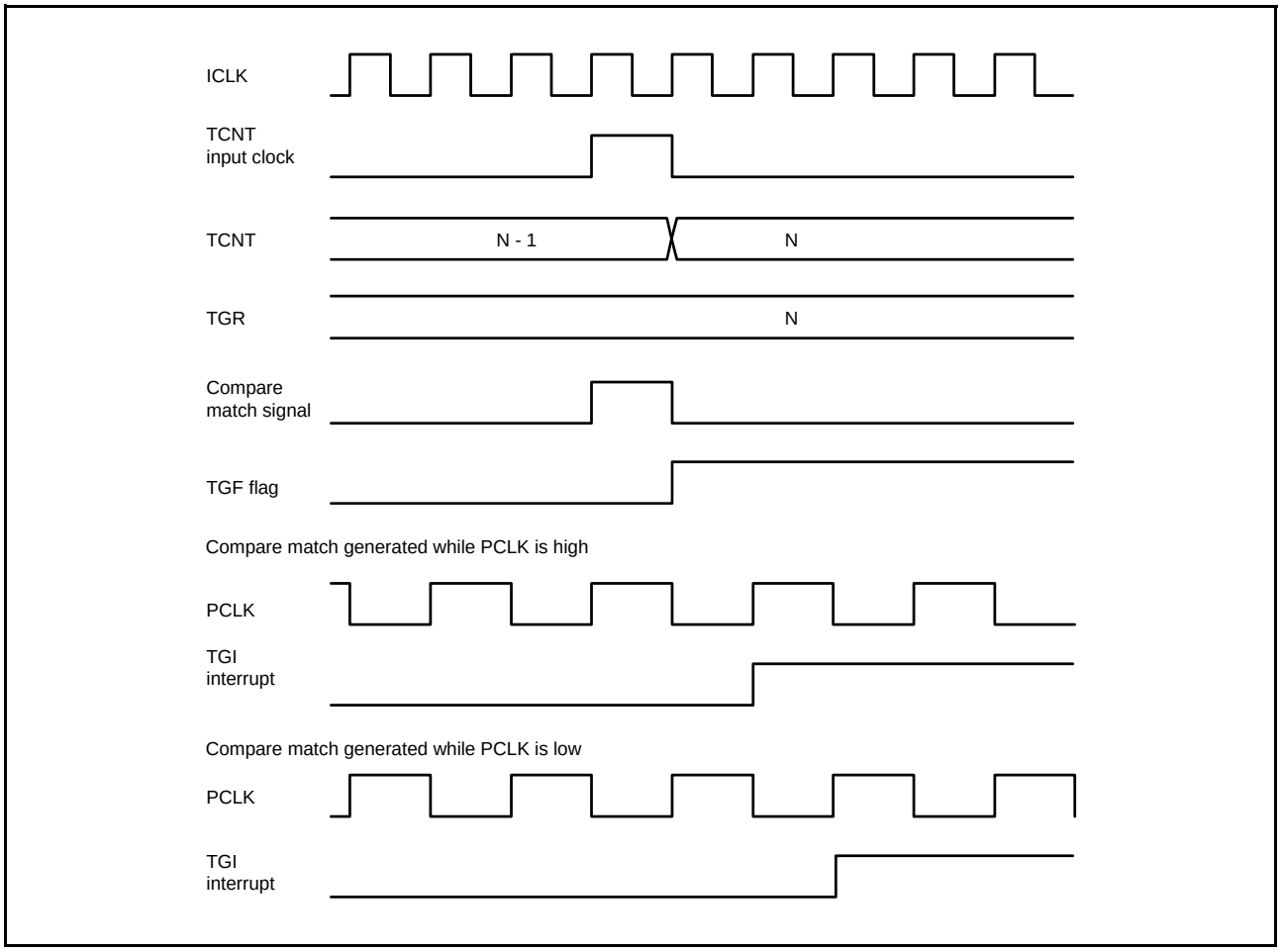


Figure 16.118 TGI Interrupt Timing (Compare Match) (MTU5)

(2) Timing for TGF Flag Setting by Input Capture

Figure 16.119 and Figure 16.120 show the timing of TGF flag setting in TSR on input capture and the TGI interrupt request signal timing.

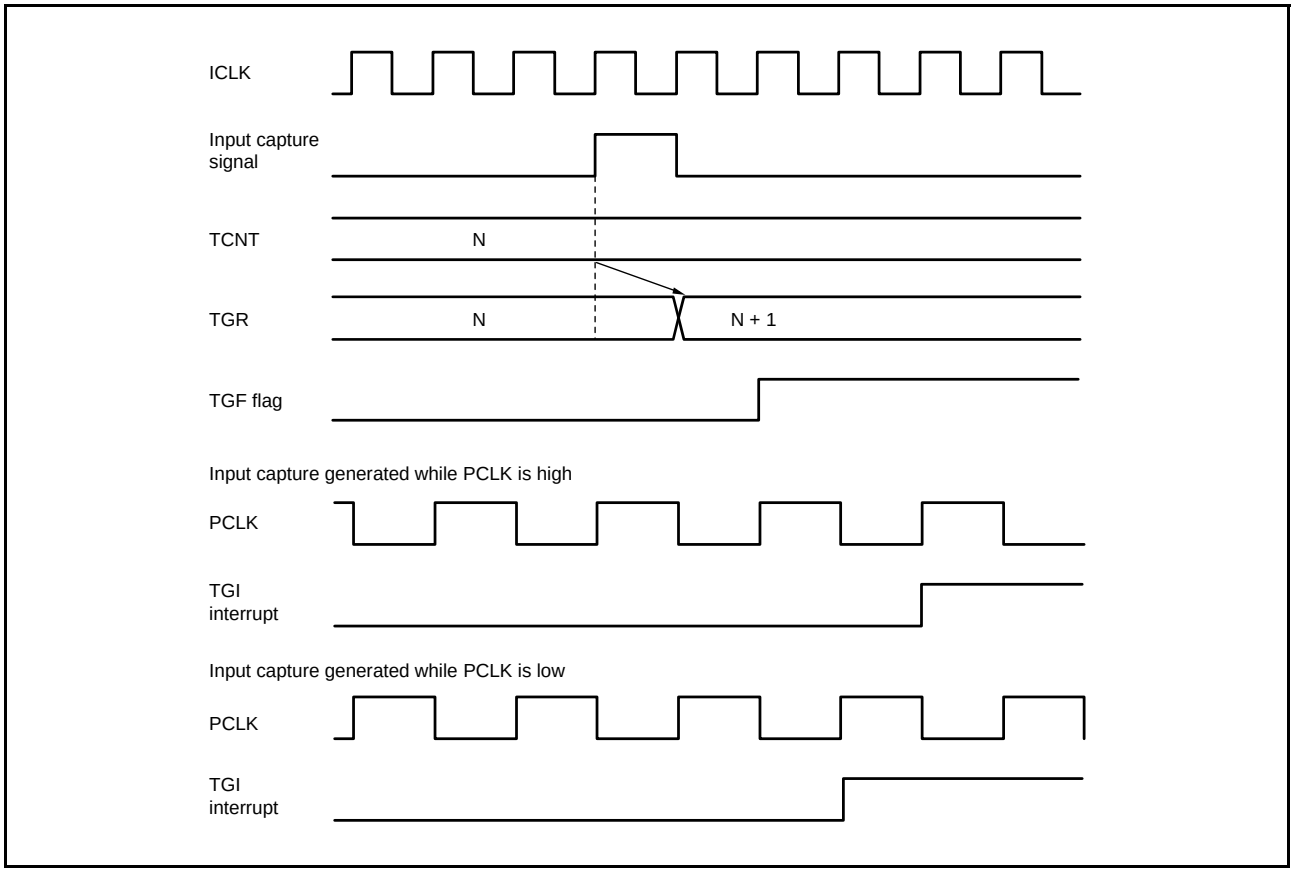


Figure 16.119 TGI Interrupt Timing (Input Capture) (MTU0 to MTU4, MTU6, and MTU7)

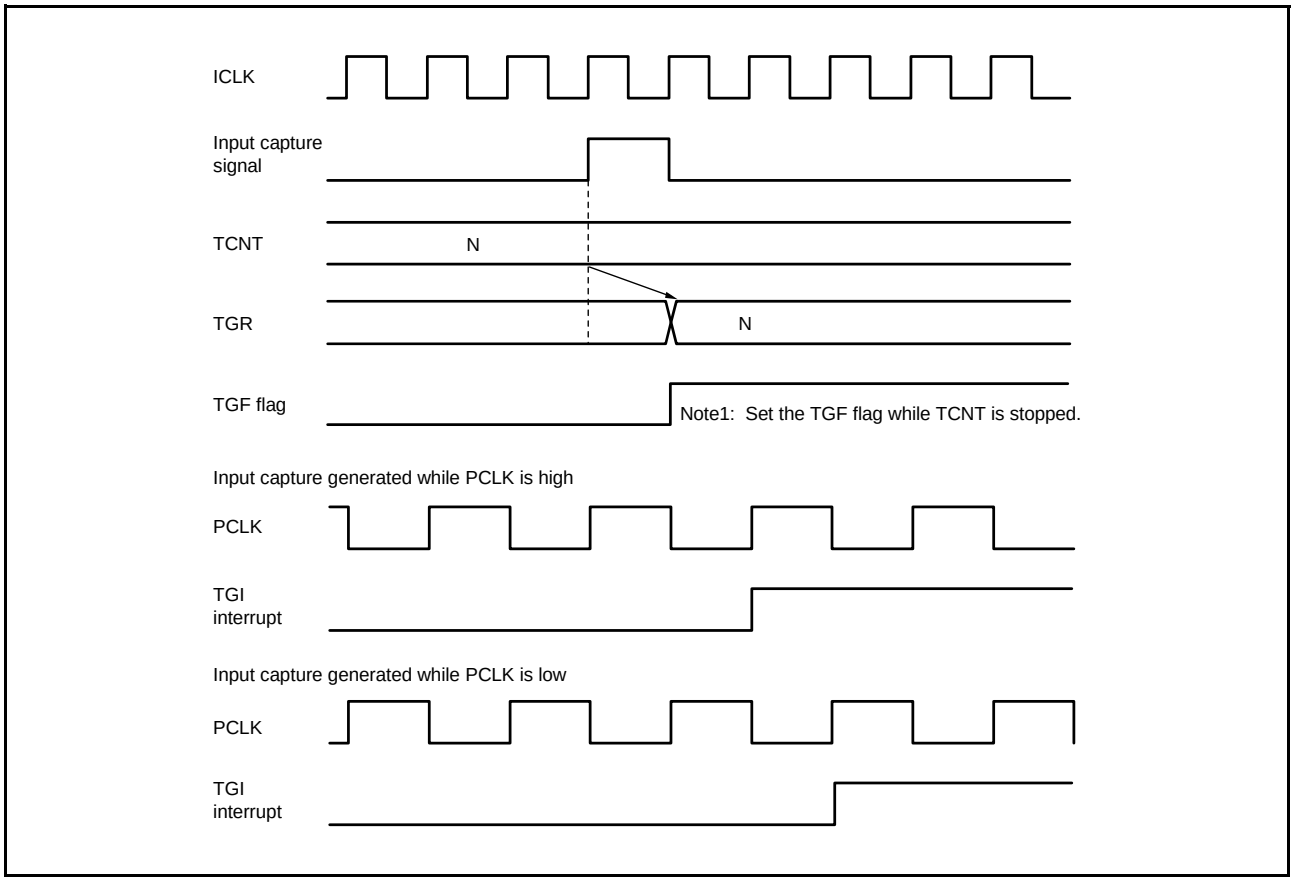


Figure 16.120 TGI Interrupt Timing (Input Capture) (MTU5)

(3) TCFV and TCFU Interrupt Timing

Figure 16.121 shows the timing of TCFV flag setting in TSR on overflow and the TCIV interrupt request signal timing. Figure 16.122 shows the timing of TCFU flag setting in TSR on underflow and the TCIU interrupt request signal timing.

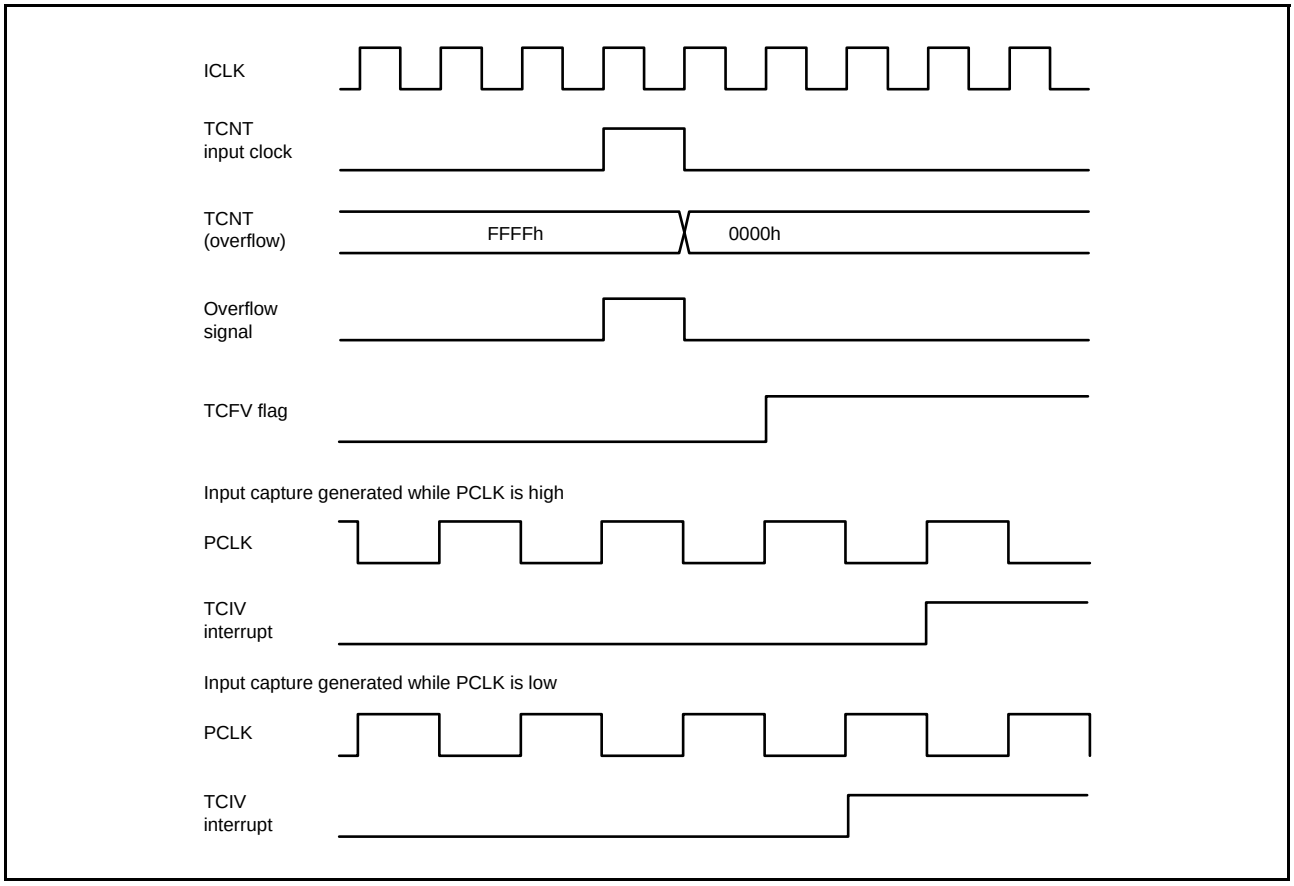


Figure 16.121 TCIV Interrupt Setting Timing

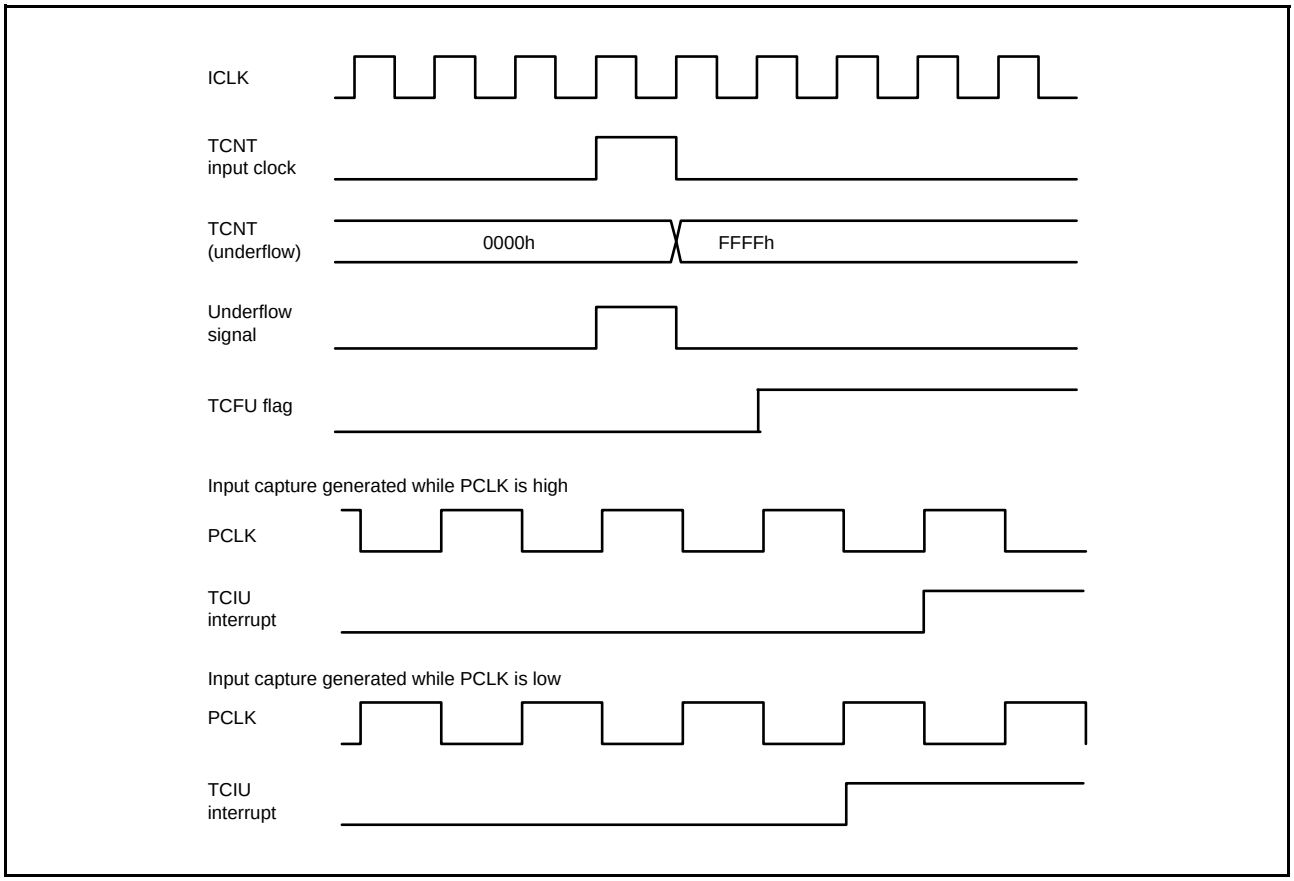


Figure 16.122 TCIU Interrupt Setting Timing

(4) Status Flag Clearing Timing

After the CPU reads a status flag as 1, it is cleared by writing 0 to it. Figure 16.123 shows the timing for status flag clearing by the CPU.

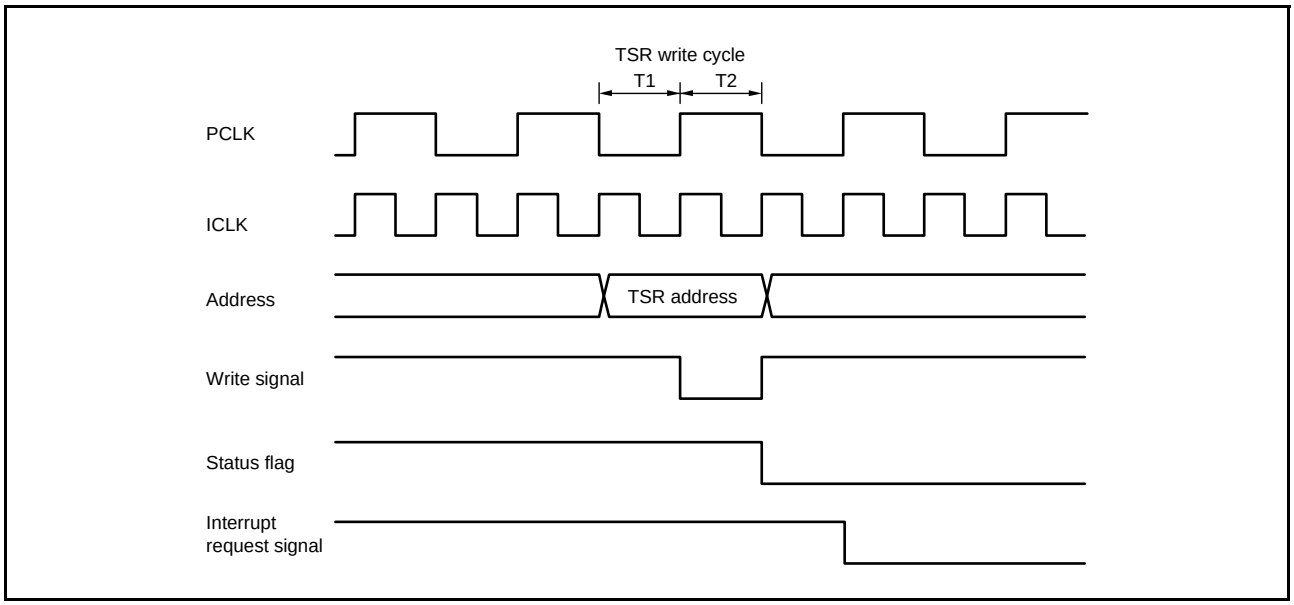


Figure 16.123 Timing for Status Flag Clearing by CPU (MTU0 to MTU7)

16.6 Usage Notes

16.6.1 Module Stop Function Setting

MTU3 operation can be disabled or enabled using the module stop control register. MTU3 operation is stopped with the initial setting. Register access is enabled by clearing the module clock stop mode. For details, refer to section 9, Low Power Consumption.

16.6.2 Input Clock Restrictions

The input clock pulse width must be at least 1.5 states for single-edge detection, and at least 2.5 states for both-edge detection. The MTU3 will not operate properly at narrower pulse widths.
In phase counting mode, the phase difference and overlap between the two input clocks must be at least 1.5 states, and the pulse width must be at least 2.5 states. Figure 16.124 shows the input clock conditions in phase counting mode.

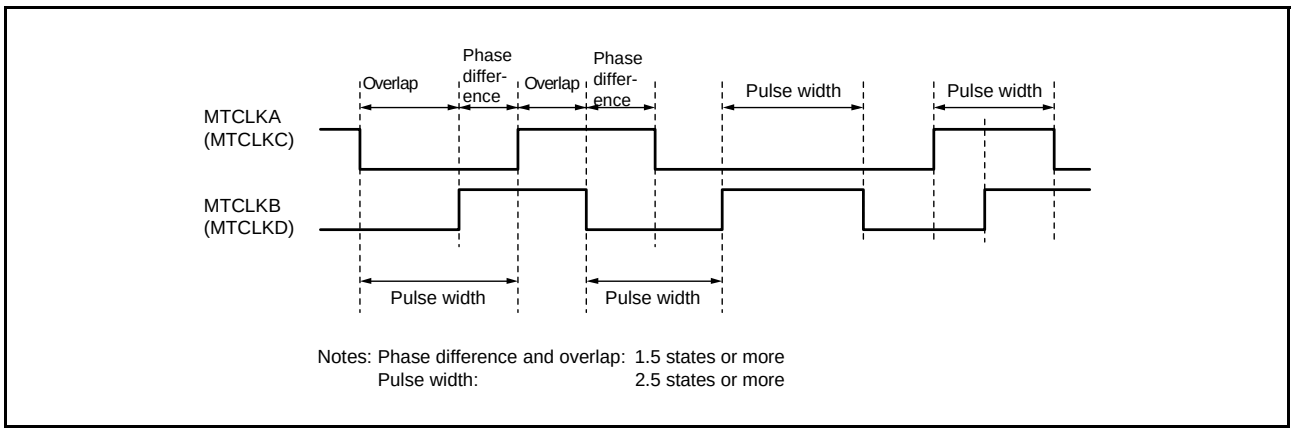


Figure 16.124 Phase Difference, Overlap, and Pulse Width in Phase Counting Mode

16.6.3 Note on Cycle Setting

When counter clearing on compare match is set, TCNT is cleared in the final state in which it matches the TGR value (the point at which TCNU updates the matched count value). Consequently, the actual counter frequency is given by the following formula:

- MTU0 to MTU4, MTU6, and MTU7

$$f = \frac{ICLK}{(N + 1)}$$

- MTU5

$$f = \frac{ICLK}{N}$$

f: Counter frequency
ICLK: MTU3 clock operating frequency
N: TGR setting

16.6.4 Contention between TCNT Write and Clear Operations

If the counter clear signal is generated in the T2 state of a TCNT write cycle, TCNT clearing takes precedence and TCNT write operation is not performed.

Figure 16.125 shows the timing in this case.

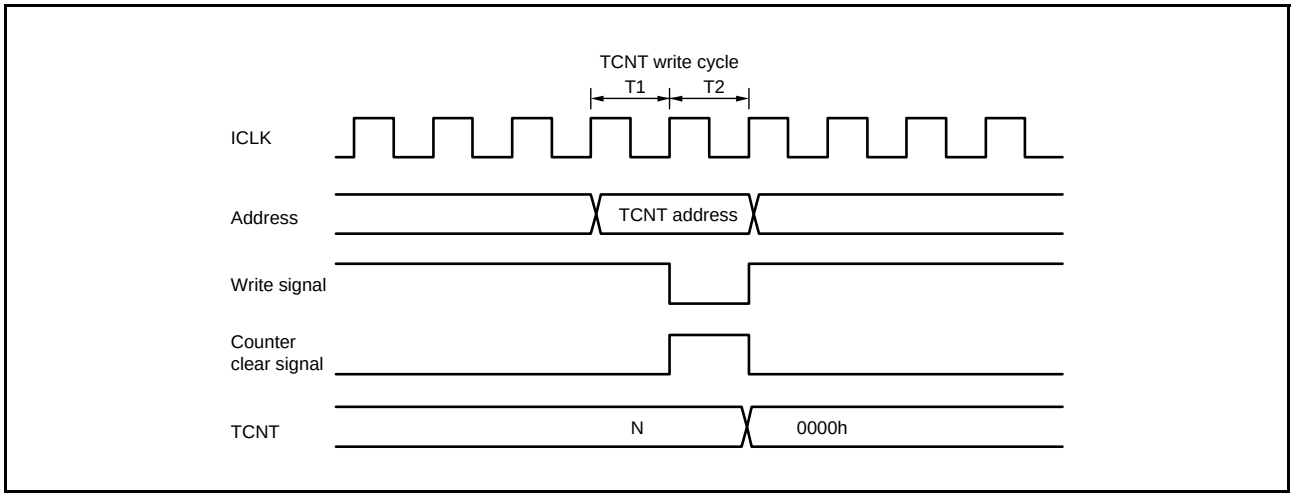


Figure 16.125 Contention between TCNT Write and Clear Operations

16.6.5 Contention between TCNT Write and Increment Operations

If incrementing occurs in the T2 state of a TCNT write cycle, TCNT write operation takes precedence and TCNT is not incremented.

Figure 16.126 shows the timing in this case.

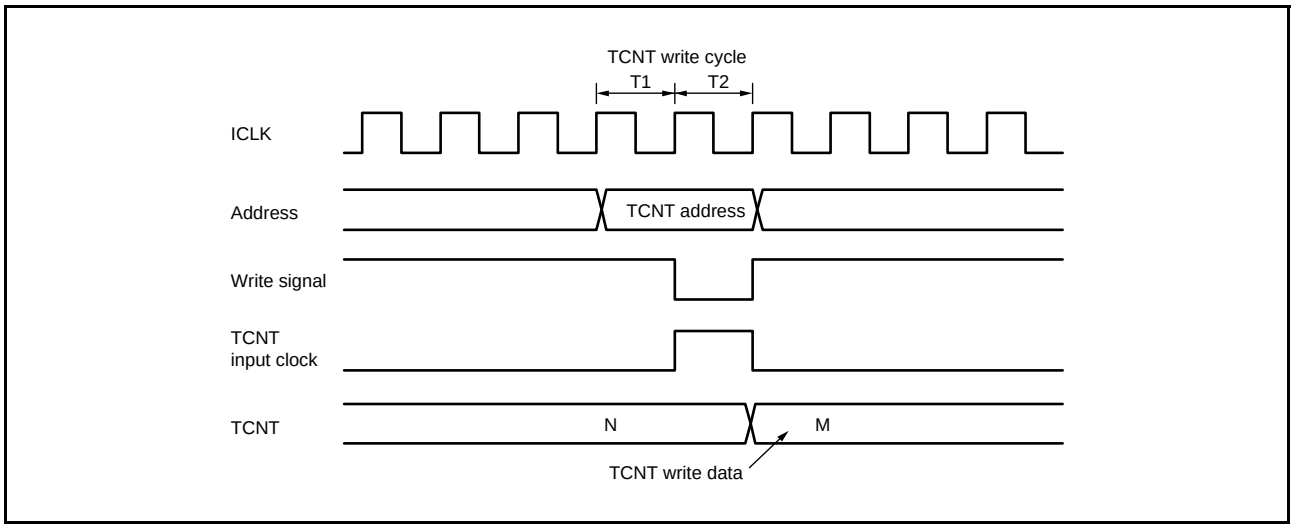


Figure 16.126 Contention between TCNT Write and Increment Operations

16.6.6 Contention between TGR Write Operation and Compare Match

If a compare match occurs in the T2 state of a TGR write cycle, TGR write operation is executed and the compare match signal is also generated.
Figure 16.127 shows the timing in this case.

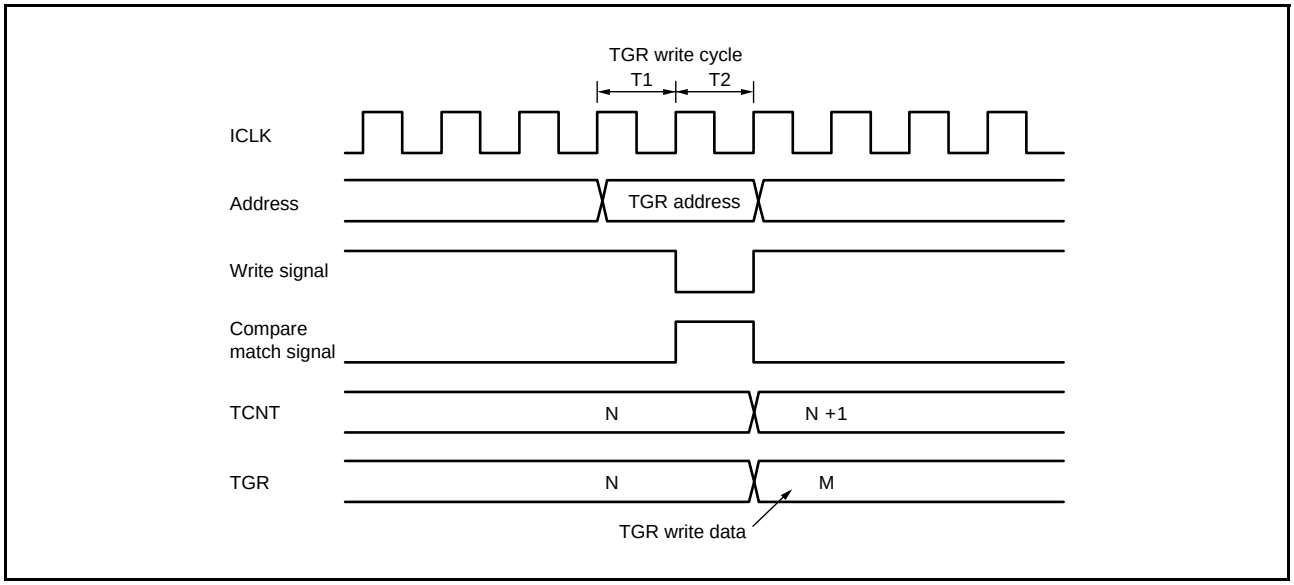


Figure 16.127 Contention between TGR Write Operation and Compare Match

16.6.7 Contention between Buffer Register Write Operation and Compare Match

If a compare match occurs in the T2 state in a TGR write cycle, the data before write operation is transferred to TGR by the buffer operation.
Figure 16.128 shows the timing in this case.

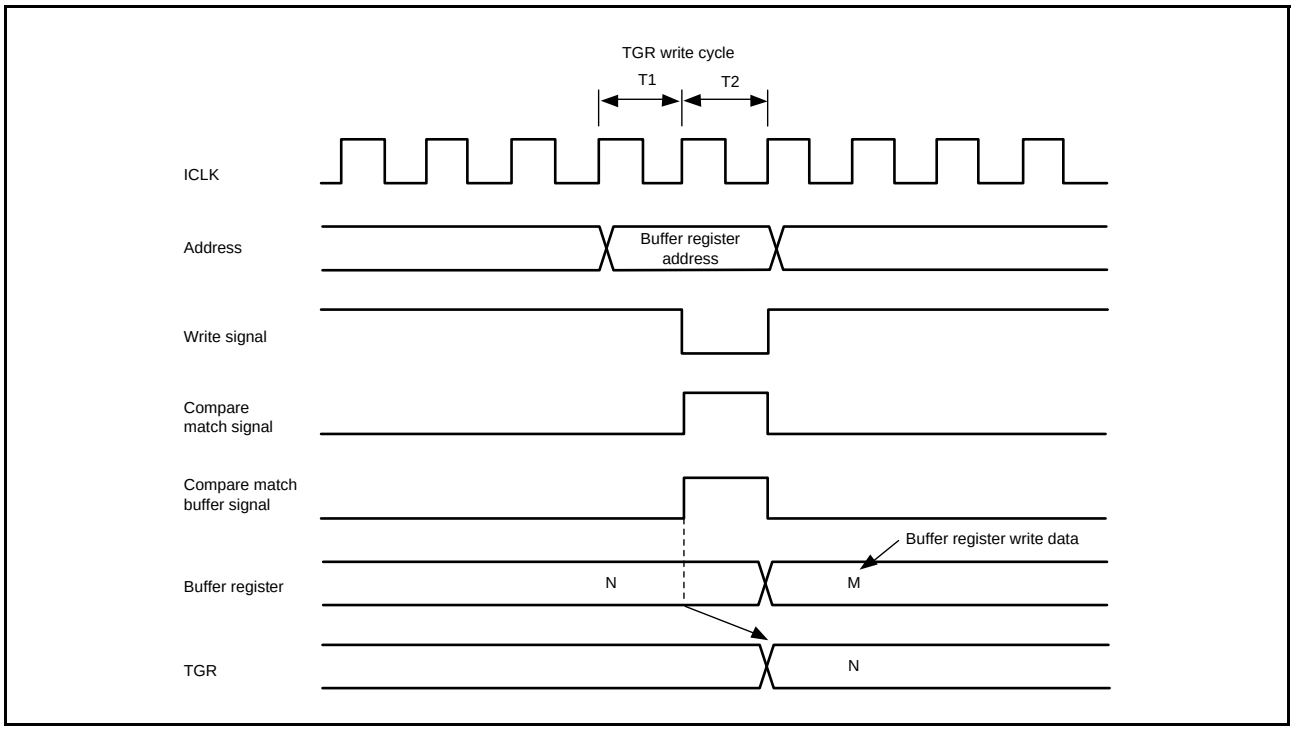


Figure 16.128 Contention between Buffer Register Write Operation and Compare Match

16.6.8 Contention between Buffer Register Write and TCNT Clear Operations

When the buffer transfer timing is set at the TCNT clear timing by the buffer transfer mode register (TBTM), if TCNT clearing occurs in the T2 sate in a TGR write cycle, the data before write operation is transferred to TGR by the buffer operation.

Figure 16.129 shows the timing in this case.

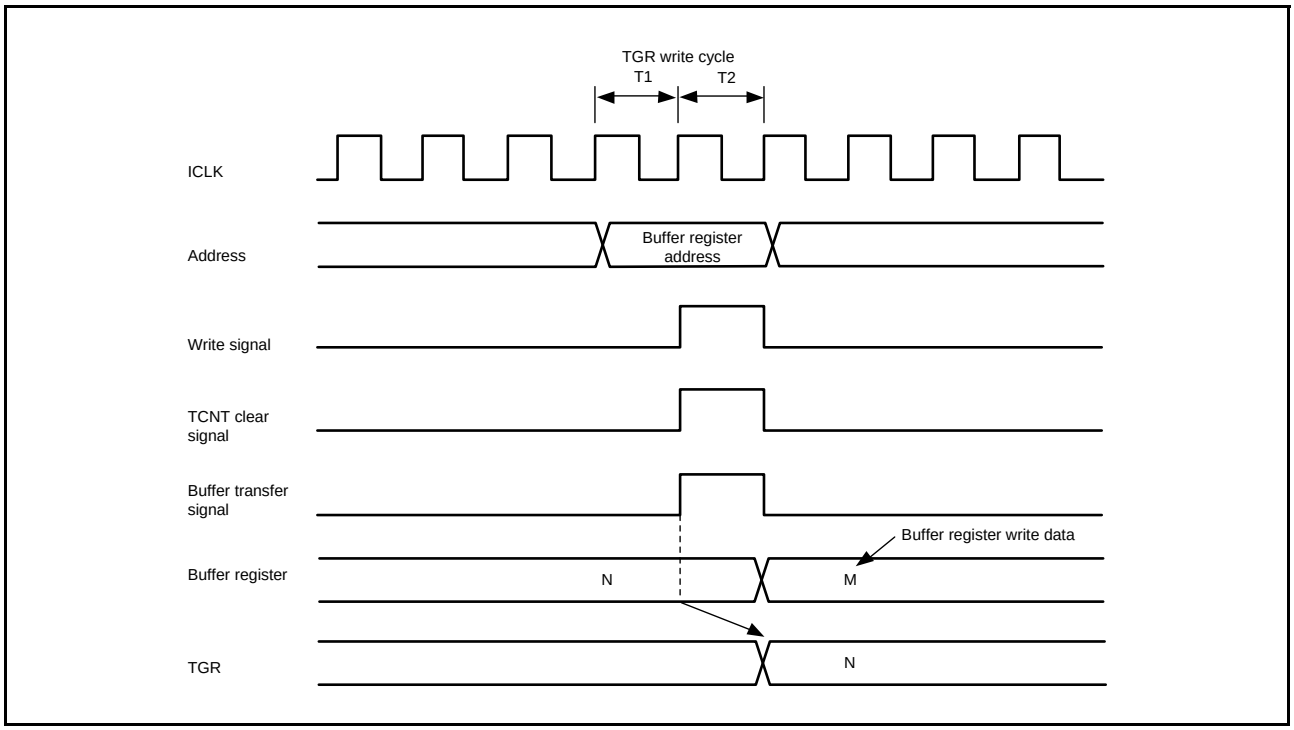


Figure 16.129 Contention between Buffer Register Write and TCNT Clear Operations

16.6.9 Contention between TGR Read Operation and Input Capture

If an input capture signal is generated in the T1 state in a TGR read cycle, the data before input capture transfer is read in MTU0 to MTU4, MTU6, and MTU7, and the data after input capture transfer in MTU5.
Figure 16.130 and Figure 16.131 show the timing in this case.

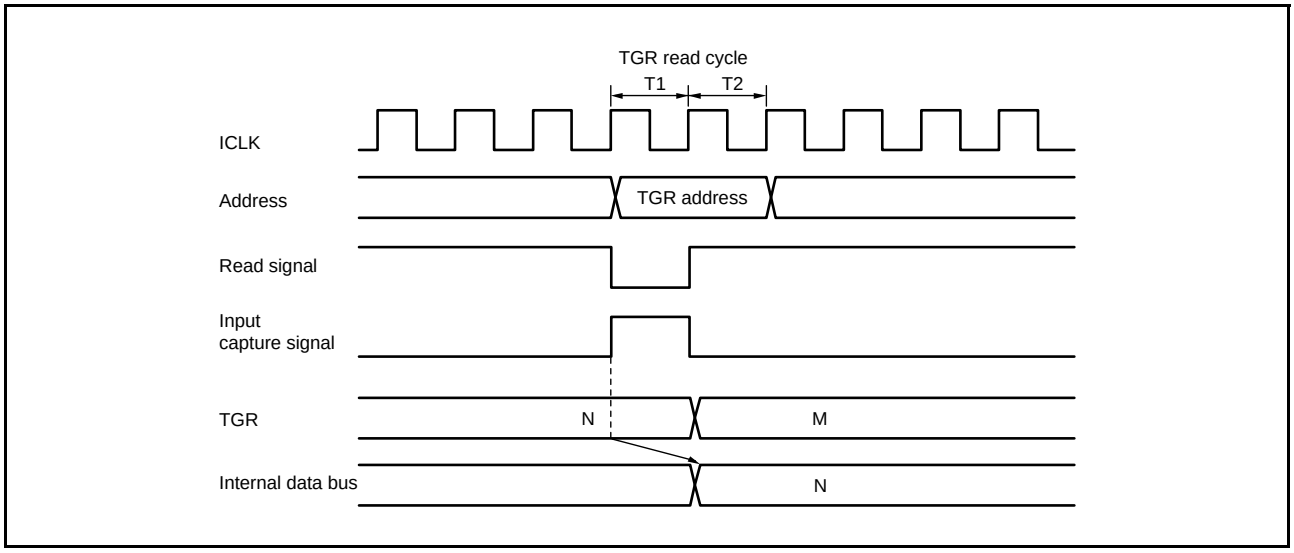


Figure 16.130 Contention between TGR Read Operation and Input Capture (MTU0 to MTU4, MTU6, and MTU7)

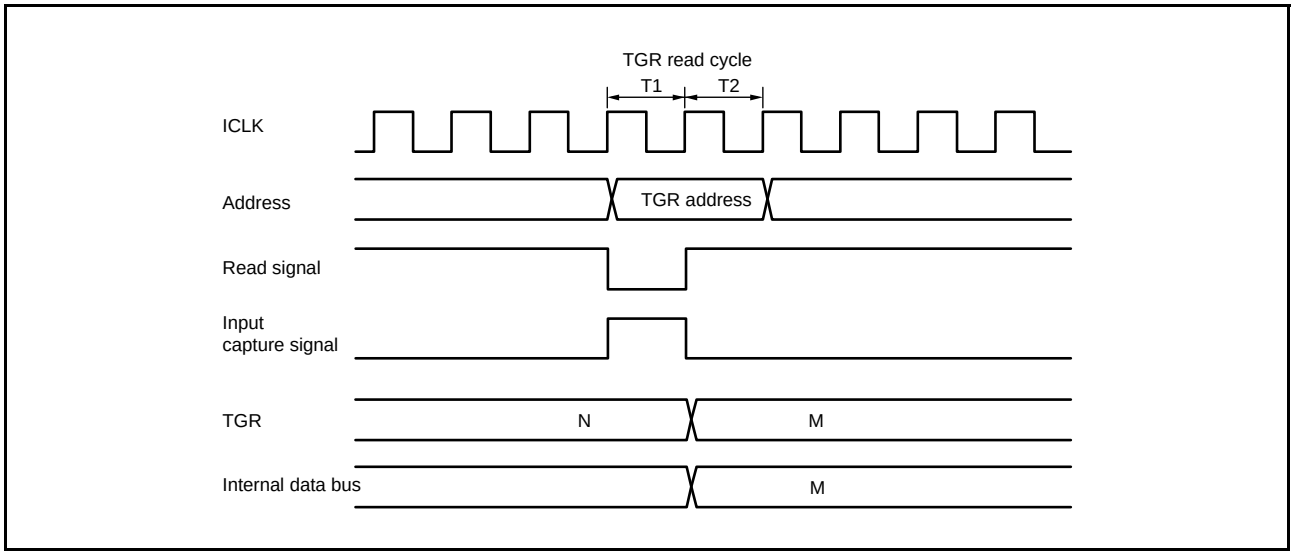


Figure 16.131 Contention between TGR Read Operation and Input Capture (MTU5)

16.6.10 Contention between TGR Write Operation and Input Capture

If an input capture signal is generated in the T2 state in a TGR write cycle, the input capture operation takes precedence and the TGR write operation is not performed in MTU0 to MTU4, MTU6, and MTU7. In cMTU5, the TGR write operation is performed and the input capture signal is generated.
Figure 16.132 and Figure 16.133 show the timing in this case.

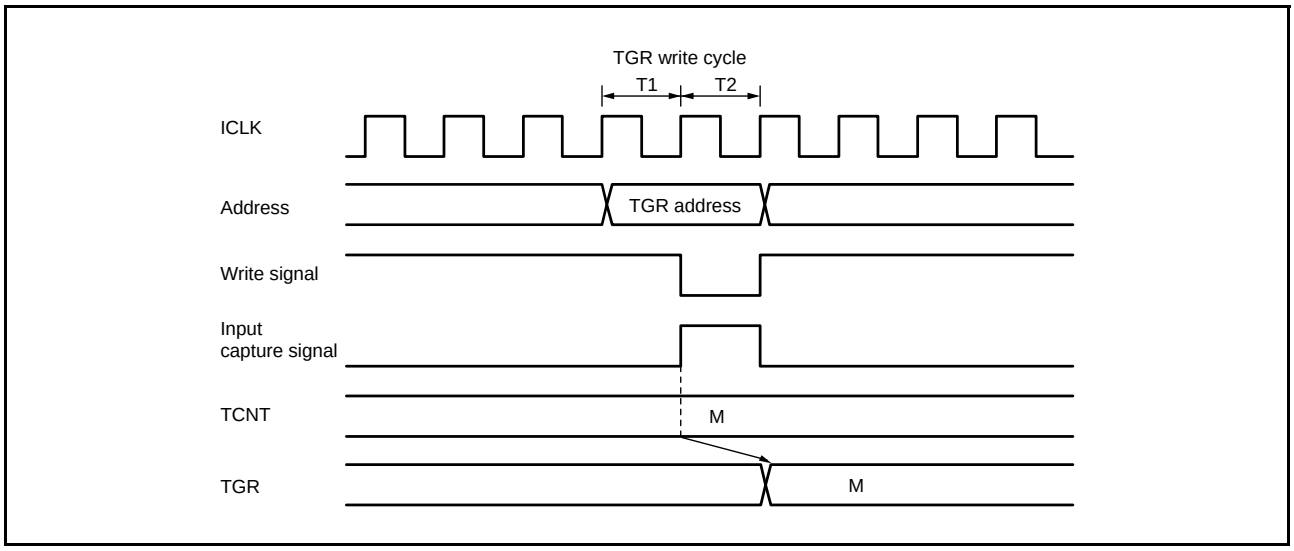


Figure 16.132 Contention between TGR Write Operation and Input Capture (MTU0 to MTU4, MTU6, and MTU7)

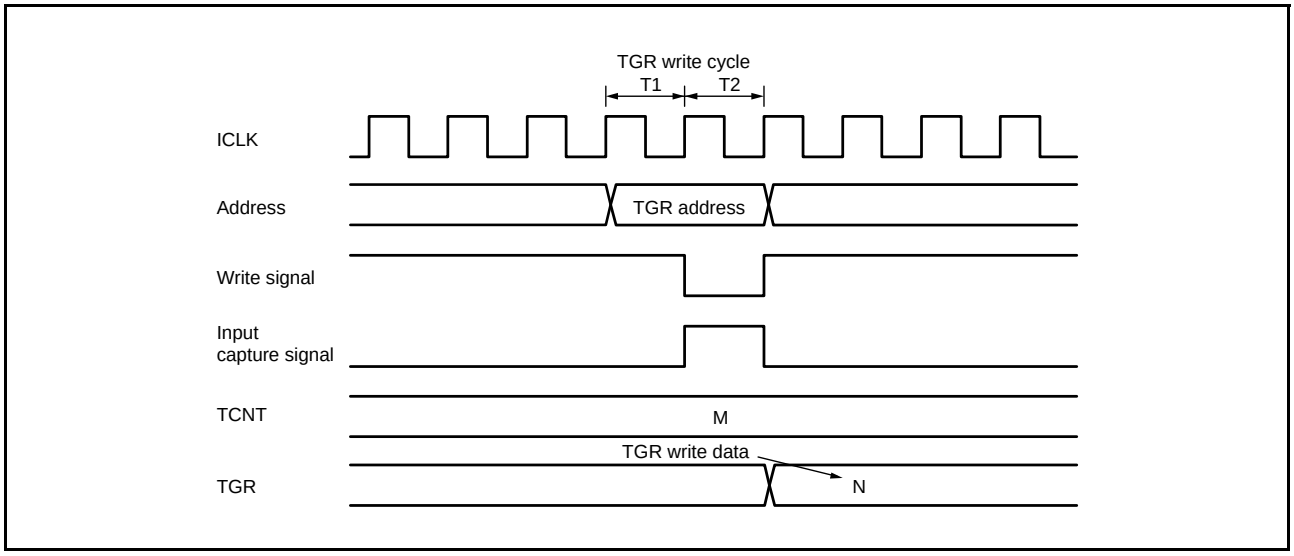


Figure 16.133 Contention between TGR Write Operation and Input Capture (MTU5)

16.6.11 Contention between Buffer Register Write Operation and Input Capture

If an input capture signal is generated in the T2 state in a buffer register write cycle, the buffer operation takes precedence and the buffer register write operation is not performed.
Figure 16.134 shows the timing in this case.

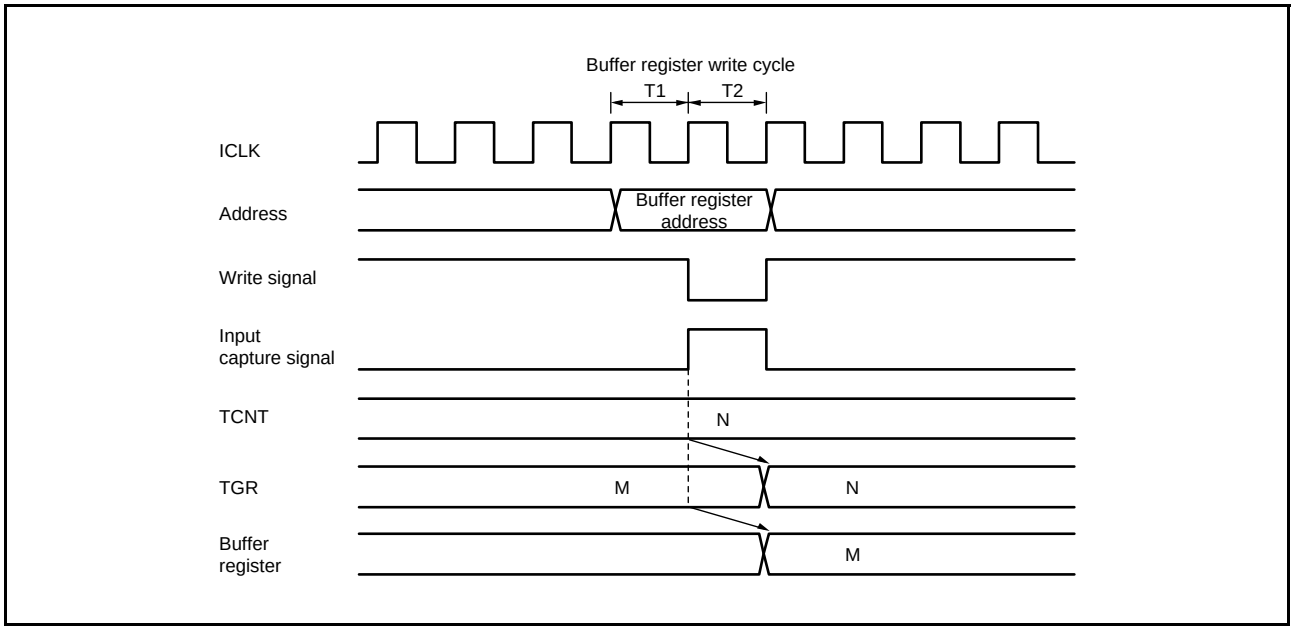


Figure 16.134 Contention between Buffer Register Write Operation and Input Capture

16.6.12 Contention between MTU2.TCNT Write Operation and Overflow/Underflow in Cascaded Operation

With timer counters MTU1.TCNT and MTU2.TCNT in a cascade, when a contention occurs between MTU1.TCNT counting (an MTU2.TCNT overflow/underflow) and the MTU2.TCNT write cycle, the MTU2.TCNT write operation is performed and the MTU1.TCNT count signal is disabled. In this case, if MTU1.TGRA works as a compare match register and there is a match between the MTU1.TGRA and MTU1.TCNT values, a compare match signal is issued. Furthermore, when the MTU1.TCNT count clock is selected as the input capture source of MTU0, MTU0.TGRA to MTU0.TGRD work in input capture mode. In addition, when the MTU0.TGRC compare match/input capture is selected as the input capture source of MTU1.TGRB, MTU1.TGRB works in input capture mode.

Figure 16.135 shows the timing in this case.

When setting the TCNT clearing function in cascaded operation, be sure to synchronize MTU1 and MTU2.

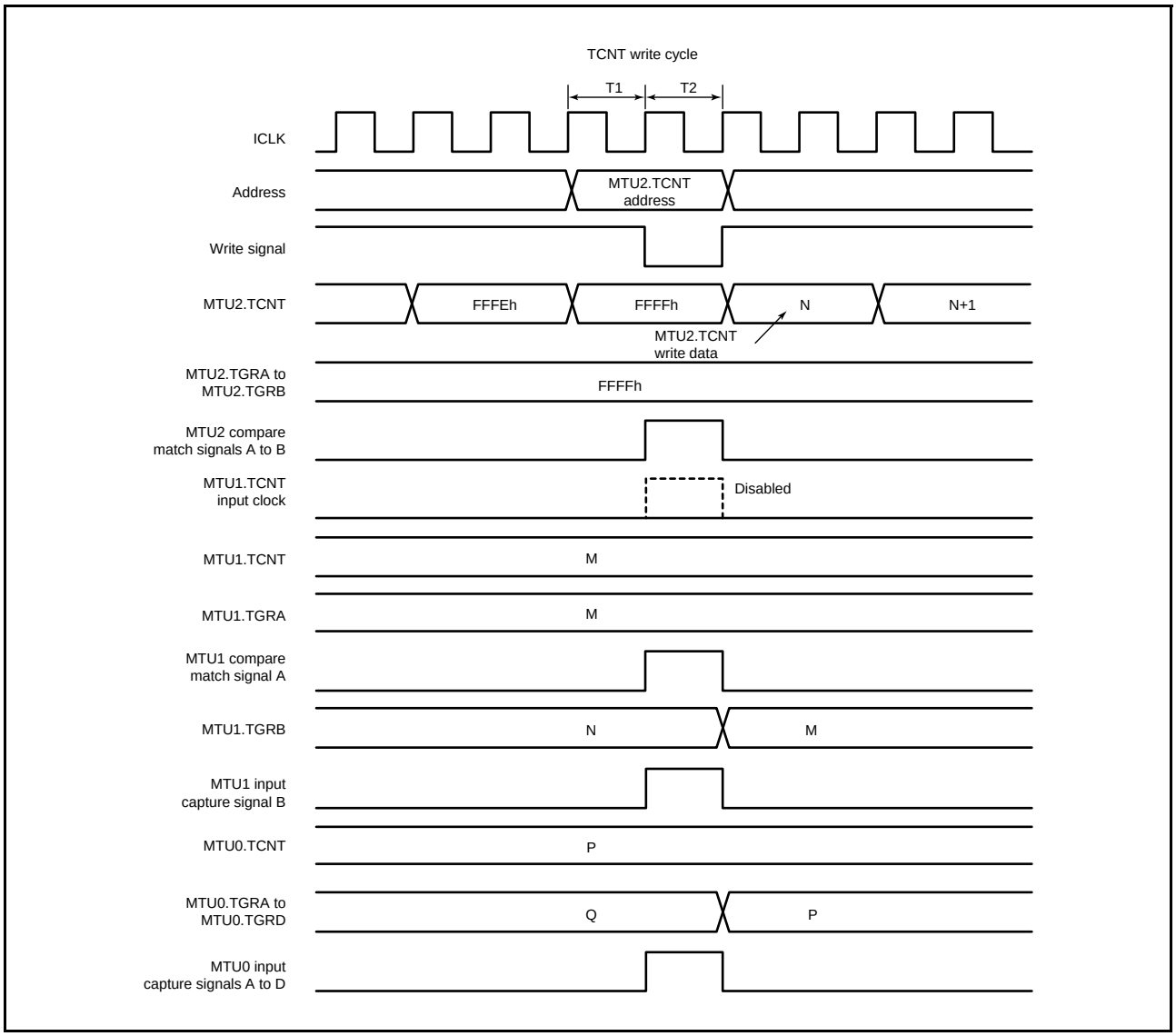


Figure 16.135 Contention between MTU2.TCNT Write Operation and Overflow/Underflow in Cascaded Operation

16.6.13 Counter Value when Stopped in Complementary PWM Mode

When counting operation in MTU3.TCNT and MTU4.TCNT (MTU6.TCNT and MTU7.TCNT) is stopped in complementary PWM mode, the MTU3.TCNT (MTU6.TCNT) value is set to the timer dead time register (TDDRA (TDDRB)) value and MTU4.TCNT (MTU7.TCNT)is set to 0000h.
When operation is restarted in complementary PWM mode, counting begins automatically from the initial setting state. Figure 16.136 shows this operation.
When counting begins in another operating mode, be sure to make initial settings in MTU3.TCNT and MTU4.TCNT (MTU6.TCNT and MTU7.TCNT).

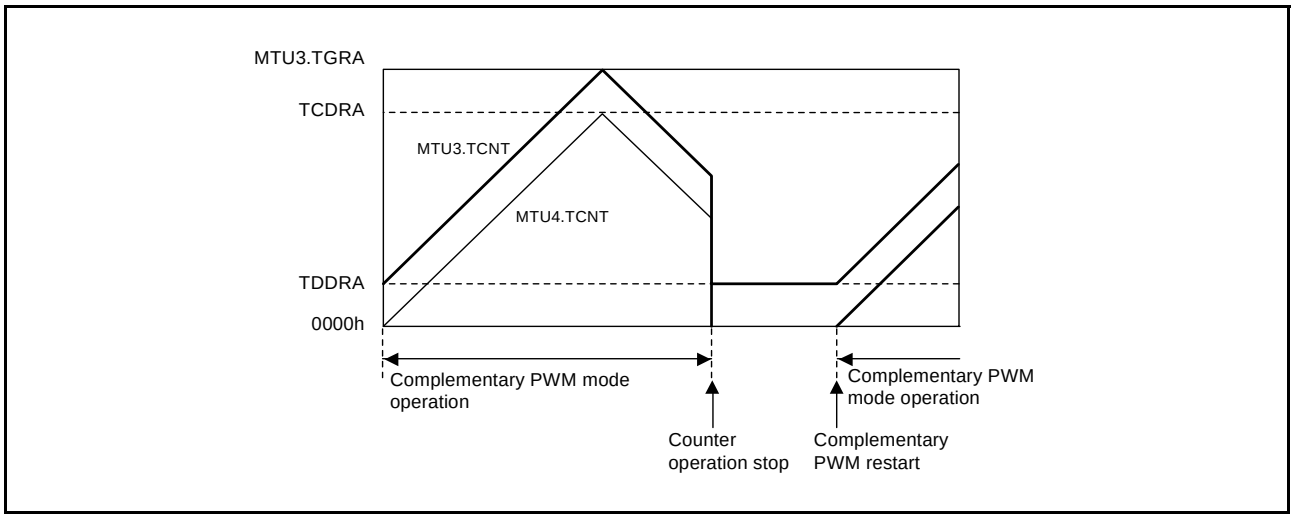


Figure 16.136 Counter Value when Stopped in Complementary PWM Mode

16.6.14 Buffer Operation Setting in Complementary PWM Mode

When modifying the PWM cycle set register (MTU3.TGRA or MTU6.TGRA), timer cycle data register (TCDRA or TCDRB), and duty set registers (MTU3.TGRB, MTU4.TGRA, and MTU4.TGRB (MTU6.TGRB, MTU7.TGRA, and MTU7.TGRB)) in complementary PWM mode, be sure to use buffer operation. In addition, set the BFA and BFB bits in MTU4.TMDR1 (MTU7.TMDR1) to 0. The MTIOC4C (MTIOC7C) pin cannot output waveforms if the BFA bit in MTU4.TMDR1 (MTU7.TMDR1) is set to 1. Likewise, the MTIOC4D (MTIOC7D) pin cannot output waveforms if the BFB bit in MTU4.TMDR1 (MTU7.TMDR1) is set to 1.
In complementary PWM mode, buffer operation in MTU3 and MTU4 (or MTU6 and MTU7) depends on the settings in bits BFA and BFB of MTU3.TMDR1 (MTU6.TMDR1). When the BFA bit in MTU3.TMDR1 (MTU6.TMDR1) is set to 1, MTU3.TGRC (MTU6.TGRC) functions as a buffer register for MTU3.TGRA (MTU6.TGRA). At the same time, MTU4.TGRC (MTU7.TGRC) functions as a buffer register for MTU4.TGRA (MTU7.TGRA), and TCBRA (TCBRB) functions as a buffer register for TCDRA (TCDRB).

16.6.15 Buffer Operation and Compare Match Flags in Reset-Synchronized PWM Mode

When setting buffer operation in reset-synchronized PWM mode, set the BFA and BFB bits in MTU4.TMDR1 (MTU7.TMDR1) to 0. The MTIOC4C (MTIOC7C) pin cannot output waveforms if the BFA bit in MTU4.TMDR1 (MTU7.TMDR1) is set to 1. Likewise, the MTIOC4D (MTIOC7D) pin cannot output waveforms if the BFB bit in MTU4.TMDR1 (MTU7.TMDR1) is set to 1.

In reset-synchronized PWM mode, buffer operation in MTU3 and MTU4 (or MTU6 and MTU7) depends on the settings in the BFA and BFB bits of MTU3.TMDR1 (MTU6.TMDR1). For example, if the BFA bit in MTU3.TMDR1 (MTU6.TMDR1) is set to 1, MTU3.TGRC (MTU6.TGRC) functions as a buffer register for MTU3.TGRA (MTU6.TGRA). At the same time, MTU4.TGRC (MTU7.TGRC) functions as a buffer register for MTU4.TGRA (MTU7.TGRA).

While the MTU3.TGRC (MTU6.TGRC) and MTU3.TGRD (MTU6.TGRD) are operating as buffer registers, the TGFC and TGFD bits in MTU3.TSR and MTU4.TSR (MTU6.TSR and MTU7.TSR) are never set.

Figure 16.137 shows an example of MTU3.TGR (MTU6.TGR), MTU4.TGR (MTU7.TGR), MTIOC3 (MTIOC6), and MTIOC4 (MTIOC7) operation with the BFA and BFB bits in MTU3.TMDR1 (MTU6.TMDR1) set to 1 and the BFA and BFB bits in MTU4.TMDR1 (MTU7.TMDR1) set to 0.

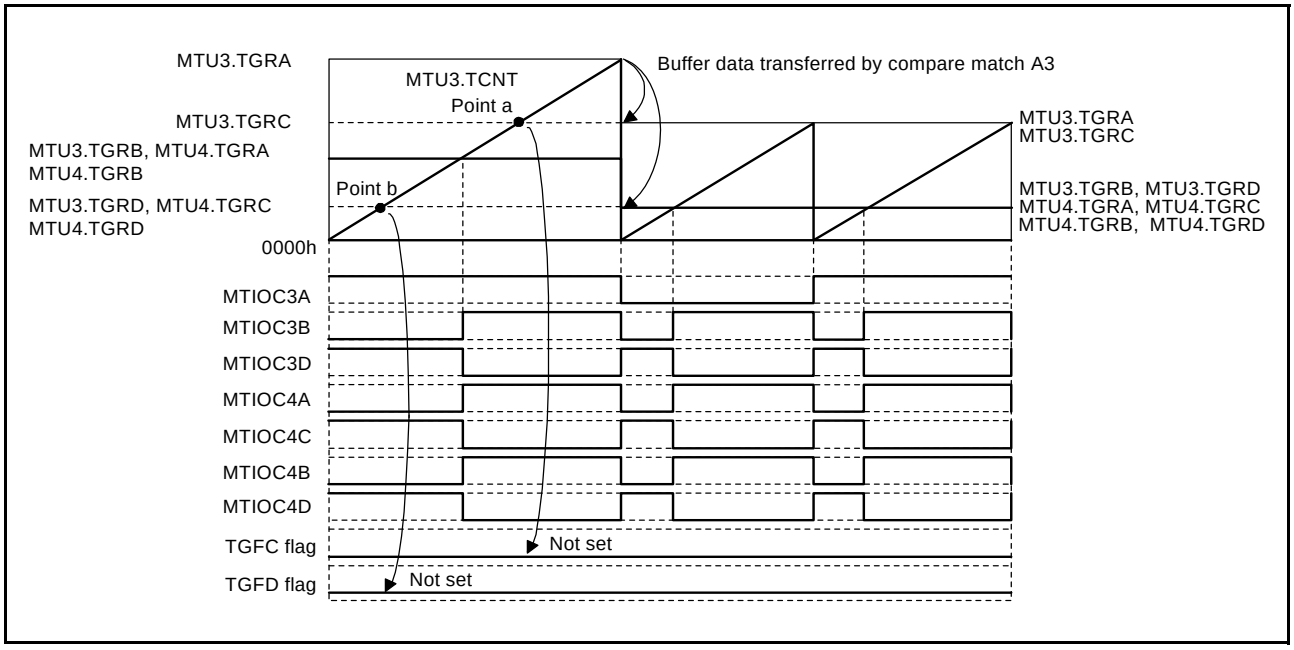


Figure 16.137 Buffer Operation and Compare Match Flags in Reset-Synchronized PWM Mode

16.6.16 Overflow Flags in Reset-Synchronized PWM Mode

After reset-synchronized PWM mode is selected, MTU3.TCNT and MTU4.TCNT (MTU6.TCNT and MTU7.TCNT) start counting when the CST3 (CST6) bit of TSTRA (TSTRB) is set to 1. In this state, the MTU4.TCNT (MTU7.TCNT) count clock source and count edge are determined by the MTU3.TCR (MTU6.TCR) setting.
In reset-synchronized PWM mode, with cycle register MTU3.TGRA (MTU6.TGRA) set to FFFFh and the MTU3.TGRA (MTU6.TGRA) compare match selected as the counter clearing source, MTU3.TCNT and MTU4.TCNT (MTU6.TCNT and MTU7.TCNT) count up to FFFFh, then a compare match occurs with MTU3.TGRA (MTU6.TGRA), and MTU3.TCNT and MTU4.TCNT (MTU6.TCNT and MTU7.TCNT) are both cleared. In this case, the TCFV flag in TSR is not set.
Figure 16.138 shows an example of TCFV flag operation in reset-synchronized PWM mode with cycle register MTU3.TGRA (MTU6.TGRA) set to FFFFh and the MTU3.TGRA (MTU6.TGRA) compare match specified for the counter clearing source without synchronous operation setting.

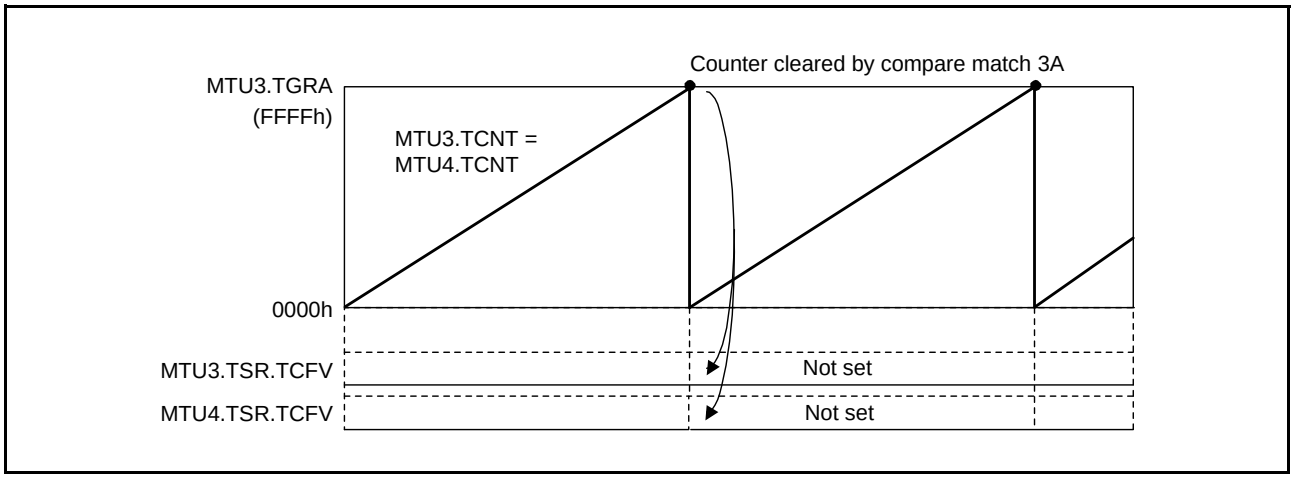


Figure 16.138 Overflow Flags in Reset-Synchronized PWM Mode

16.6.17 Contention between Overflow/Underflow and Counter Clearing

If an overflow/underflow and counter clearing occur simultaneously, the TCFV/FCFU flag in TSR is not set and TCNT clearing takes precedence.

Figure 16.139 shows the operation timing when a TGR compare match is specified as the clearing source and TGR is set to FFFFh.

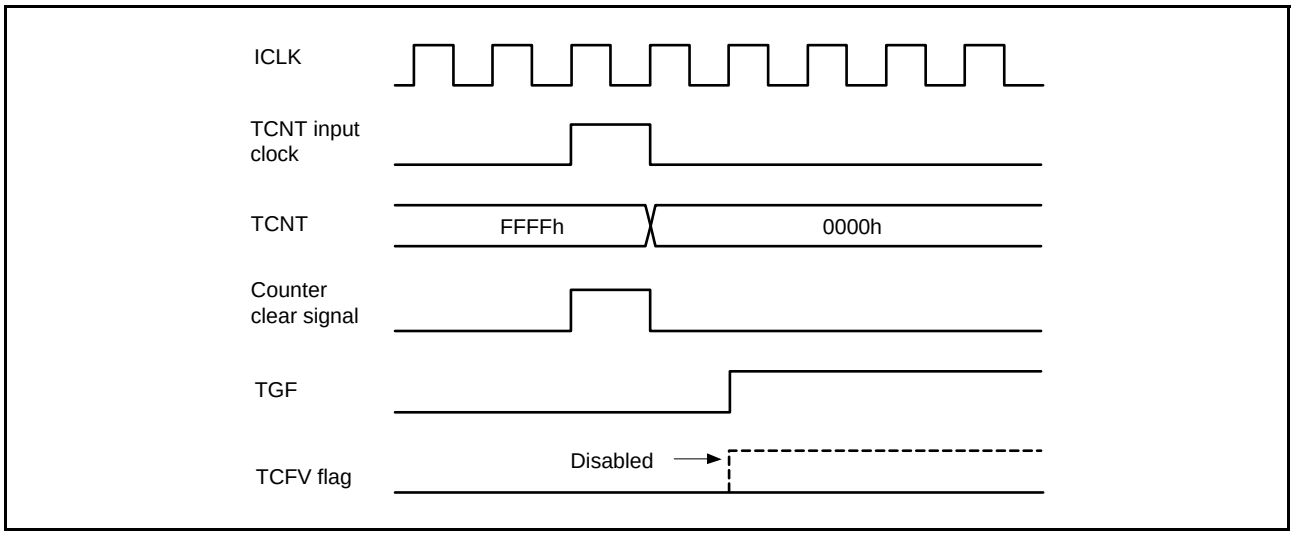


Figure 16.139 Contention between Overflow and Counter Clearing

16.6.18 Contention between TCNT Write Operation and Overflow/Underflow

If TCNT counts up or down in the T2 state in a TCNT write cycle and an overflow or an underflow occurs, the TCNT write operation takes precedence and the TCFV/TCFU flag in TSR is not set.

Figure 16.140 shows the operation timing when there is contention between TCNT write operation and overflow.

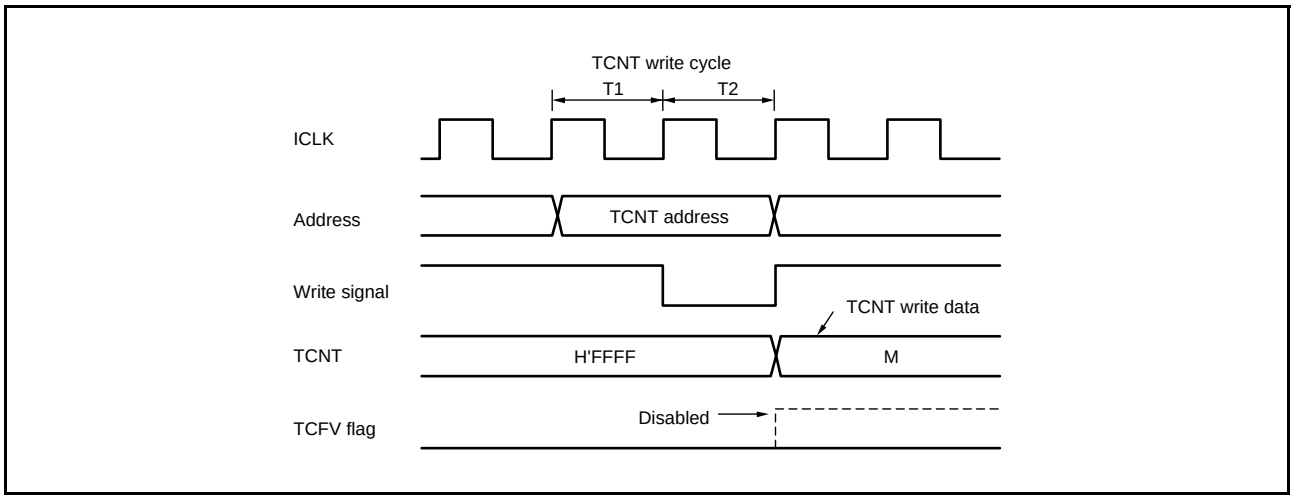


Figure 16.140 Contention between TCNT Write Operation and Overflow

16.6.19 Note on Transition from Normal Operation or PWM Mode 1 to Reset-Synchronized PWM Mode

When making a transition from normal operation or PWM mode 1 to reset-synchronized PWM mode in MTU3 and MTU4 (or MTU6 and MTU7), if the counter is stopped while the output pins (MTIOC3B, MTIOC3D, MTIOC4A, MTIOC4C, MTIOC4B, MTIOC4D, MTIOC6B, MTIOC6D, MTIOC7A, MTIOC7C, MTIOC7B, and MTIOC7D) are held at a high level and then operation is started after a transition to reset-synchronized PWM mode, the initial pin output will not be correct.

When making a transition from normal operation to reset-synchronized PWM mode, write 11h to MTU3.TIORH, MTU3.TIORL, MTU4.TIORH, and MTU4.TIORL (MTU6.TIORH, MTU6.TIORL, MTU7.TIORH, and MTU7.TIORL) to initialize the output pin state to a low level, then set the registers to the initial value (00h) before making the mode transition.

When making a transition from PWM mode 1 to reset-synchronized PWM mode, switch to normal operation, initialize the output pin state to a low level, and then set the registers to the initial value (00h) before making the transition to reset-synchronized PWM mode.

16.6.20 Output Level in Complementary PWM Mode and Reset-Synchronized PWM Mode

When MTU3 and MTU4 (or MTU6 and MTU7) are in complementary PWM mode or reset-synchronized PWM mode, the PWM waveform output level is determined by the OLSP and OLSN bits in the timer output control register (TOCR1A or TOCR1B). In complementary PWM mode or reset-synchronized PWM mode, TIOR should be set to 00h. Rather than being as set in TOCR1.OLSN, the output level in the negative phase when the TDER.TDER bit is 0 (dead time is not generated) in complementary PWM mode becomes the inverse of the normal-phase output in accord with the setting of the TOCR1.OLSP bit.

16.6.21 Simultaneous Input Capture in MTU1.TCNT and MTU2.TCNT in Cascade Connection

When timer counters 1 and 2 (MTU1.TCNT and MTU2.TCNT) operate as a 32-bit counter in cascade connection, the cascaded counter value cannot be captured successfully in some cases even if input-capture input is simultaneously done to MTIOC1A and MTIOC2A or to MTIOC1B and MTIOC2B. This is because the input timing of MTIOC1A and MTIOC2A or to MTIOC1B and MTIOC2B may not be the same when external input-capture signals input into MTU1.TCNT and MTU2.TCNT are taken in synchronization with the internal clock.

For example, MTU1.TCNT (the counter for upper 16 bits) does not capture the count-up value by an overflow from MTU2.TCNT (the counter for lower 16 bits) but captures the count value before the up-counting. In this case, the values of MTU1.TCNT = FFF1h and MTU2.TCNT = 0000h should be transferred to MTU1.TGRA and MTU2.TGRA or to MTU1.TGRB and MTU2.TGRB, but the values of MTU1.TCNT = FFF0h and MTU2.TCNT = 0000h are erroneously transferred.

A facility for simultaneous capture of MTU1.TCNT and MTU2.TCNT on input of the input-capture signal has been added to the MTU. This facility can be used to ensure there is no deviation between the timing of capture for MTU1.TCNT and MTU2.TCNT, and this makes setting up a 32-bit counter possible. For details, see section 16.2.9, Timer Input Capture Control Register (TICCR).

16.6.22 Interrupt-Skipping Function 2

When interrupt-skipping function 2 is in use and the difference between the values in MTU4.TADCORA and MTU4.TADCORB is small, correct counting of the number skipped may not be possible, in which case requests for A/D conversion will not be generated with the expected timing. The conditions listed below thus apply to these settings.
For MTU6 and MTU7, the same conditions apply to the settings of MTU7.TADCORA and MTU7.TADCORB.

(1) When the number skipped is zero for skipping function 2

- The difference between the values in MTU4.TADCORA and MTU4.TADCORB must be at least four.
- The interval of comparison for MTU4.TADCORA must be at least four cycles of ICLK (the updated value of MTU4.TADCORA is set to the previous value plus or minus at least four).
- The interval of comparison for MTU4.TADCORB must be at least four cycles of ICLK (the updated value of MTU4.TADCORB is set to the previous value plus or minus at least four).

(2) When the number skipped is one or more for skipping function 2

- The difference between the values in MTU4.TADCORA and MTU4.TADCORB must be at least two.
- The interval of comparison for MTU4.TADCORB must be at least two cycles of ICLK (the updated value of MTU4.TADCORB is set to the previous value plus or minus at least two).

16.7 MTU3 Output Pin Initialization

16.7.1 Operating Modes

The MTU3 has the following six operating modes. Waveforms can be output in any of these modes.

- Normal mode (MTU0 to MTU4, MTU6, and MTU7)
- PWM mode 1 (MTU0 to MTU4, MTU6, and MTU7)
- PWM mode 2 (MTU0 to MTU2)
- Phase counting modes 1 to 4 (MTU1 and MTU2)
- Complementary PWM mode (MTU3, MTU4, MTU6, and MTU7)
- Reset-synchronized PWM mode (MTU3, MTU4, MTU6, and MTU7)

This section describes how to initialize the MTU3 output pins in each of these modes.

16.7.2 Operation in Case of Re-Setting Due to Error during Operation

If an error occurs during MTU3 operation, MTU3 output should be cut off by the system. The output can be cut off by making necessary settings for non-active level output in the data directions registers (DDR) and data registers (DR) in the I/O ports in advance and disabling MTU3 output to switch them to general output ports; the specified non-active level will be output from the pins. MTU3 output can be disabled through TIOR settings. Complementary PWM output (MTIOC3B, MTIOC3D, MTIOC4A, MTIOC4B, MTIOC4C, MTIOC4D, MTIOC6B, MTIOC6D, MTIOC7A, MTIOC7B, MTIOC7C, and MTIOC7D) should be specified through TOERA and TOERB settings. For PWM output pins, output can also be cut by hardware, using port output enable 3 (POE3). The pin initialization procedures for re-setting due to an error during operation and the procedures for restarting in a different mode after re-setting are described below.

The MTU3 has six operating modes, as stated above. There are thus 36 mode transition combinations, but some transitions are not available with certain channel and mode combinations. Available mode transition combinations are shown in Table 16.75.

Table 16.75 Mode Transition Combinations

	Normal	PWM1	PWM2	PCM	CPWM	RPWM
Normal	(1)	(2)	(3)	(4)	(5)	(6)
PWM1	(7)	(8)	(9)	(10)	(11)	(12)
PWM2	(13)	(14)	(15)	(16)	Not available	Not available
PCM	(17)	(18)	(19)	(20)	Not available	Not available
CPWM	(21)	(22)	Not available	Not available	(23) (24)	(25)
RPWM	(26)	(27)	Not available	Not available	(28)	(29)

Normal: Normal mode
PWM1: PWM mode 1
PWM2: PWM mode 2
PCM: Phase counting modes 1 to 4
CPWM: Complementary PWM mode
RPWM: Reset-synchronized PWM mode

16.7.3 Overview of Initialization Procedures and Mode Transitions in Case of Error during Operation

- When making a transition to a mode (Normal, PWM1, PWM2, or PCM) in which the pin output level is selected by the timer I/O control register (TIOR) setting, initialize the pins by means of TIOR setting.
- In PWM mode 1, waveforms are not output to the MTIOCnB and MTIOCnD (n = 3, 4, 6, or 7) pins. If no other module outputs signals through these pins, they enter high-impedance state. To output a specified level, make necessary settings for general output ports in the data direction registers (DDR) and data registers (DR) in the I/O ports.
- In PWM mode 2, waveforms are not output to the cycle register pins. If no other module outputs signals through these pins, they enter high-impedance state. To output a specified level, make necessary settings for general output ports in the data direction registers (DDR) and data registers (DR) in the I/O ports.
- In normal mode or PWM mode 2, if TGRC and TGRD operate as buffer registers, waveforms are not output to the corresponding pins. If no other module outputs signals through these pins, they enter high-impedance state. To output a specified level, make necessary settings for general output ports in the data direction registers (DDR) and data registers (DR) in the I/O ports.
- In PWM mode 1, if either TGRC or TGRD operates as a buffer register, waveforms are not output to the corresponding pins. If no other module outputs signals through these pins, they enter high-impedance state. To output a specified level, make necessary settings for general output ports in the data direction registers (DDR) and data registers (DR) in the I/O ports.
- When making a transition to a mode (CPWM or RPWM) in which the pin output level is selected by the timer output control register (TOCR1A, TOCR2A, TOCR1B, or TOCR2B) setting, temporarily disable output in MTU3 and MTU4 (or MTU6 and MTU7) with the timer output master enable register (TOERA or TOERB). At this time, if no other module outputs signals through these pins, they enter high-impedance state. To output a specified level, make necessary settings for general output ports in the data direction registers (DDR) and data registers (DR) in the I/O ports. Switch to normal mode, perform initialization with TIOR, restore TIOR to its initial value, then operate the MTU3 in accordance with the mode setting procedure (TOCR1A setting, TOCR2A setting, TMDR1 setting, and TOERA setting (TOCR1B setting, TOCR2B setting, TMDR1 setting, and TOERB setting)).

Note: • Channel number is substituted for "n" indicated in this section.

Pin initialization procedures are described below for the numbered combinations in Table 16.75. The active level is assumed to be low.

(1) Operation when Error Occurs in Normal Mode and Operation is Restarted in Normal Mode

Figure 16.141 shows a case in which an error occurs in normal mode and operation is restarted in normal mode after re-setting.

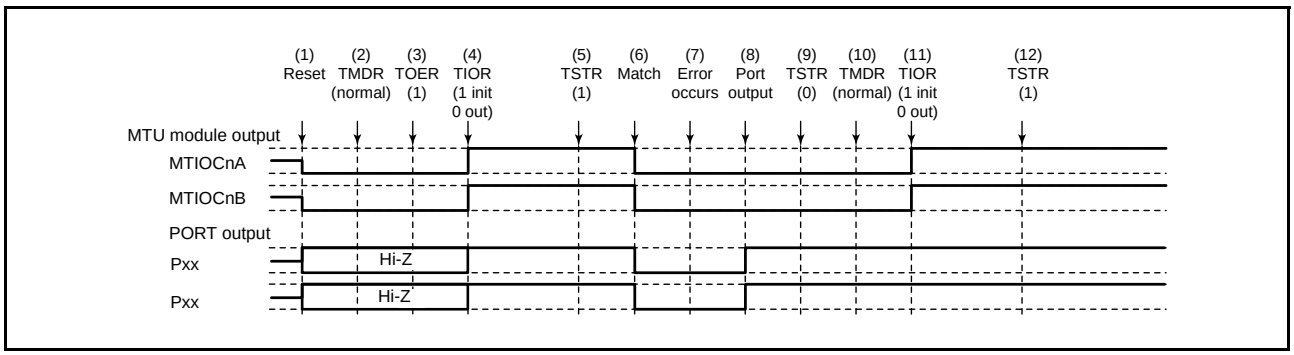


Figure 16.141 Error Occurrence in Normal Mode, Recovery in Normal Mode

(1) After a reset, the MTU3 output goes low and the ports enter high-impedance state.
(2) After a reset, the TMDR1 setting is for normal mode.
(3) For MTU3 and MTU4, enable output with TOERA before initializing the pins with TIOR.
In addition, make necessary settings in the data direction registers (DDR) and data registers (DR) in the I/O ports so that a non-active level is output from the general ports.
(4) Initialize the pins with TIOR. (In the example, the initial output is a high level, and a low level is output on compare match occurrence.)
(5) Start count operation by setting TSTRA.
(6) Output goes low on compare match occurrence.
(7) An error occurs.
(8) Disable the MTU3 output with TIOR to switch the pins to general output ports so that a non-active level is output from the pins.
(9) Stop count operation by setting TSTRA.
(10) This step is not necessary when restarting in normal mode.
(11) Initialize the pins with TIOR.
(12) Restart operation by setting TSTRA.

(2) Operation when Error Occurs in Normal Mode and Operation is Restarted in PWM Mode 1

Figure 16.142 shows a case in which an error occurs in normal mode and operation is restarted in PWM mode 1 after re-setting.

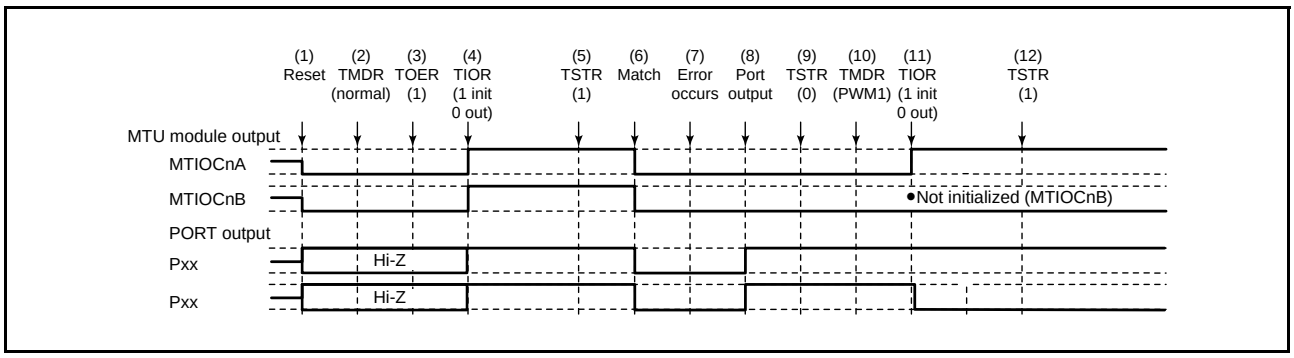


Figure 16.142 Error Occurrence in Normal Mode, Recovery in PWM Mode 1

(1) to (9) are the same as in Figure 16.141.
(10) Set PWM mode 1.
(11) Initialize the pins with TIOR. (In PWM mode 1, waveforms are not output to the MTIOCnB (MTIOCnD) pins. To output a specified level, make necessary settings for general output ports in the data direction registers (DDR) and data registers (DR) in the I/O ports.)
(12) Restart operation by setting TSTRA.

(3) Operation when Error Occurs in Normal Mode and Operation is Restarted in PWM mode 2

Figure 16.143 shows a case in which an error occurs in normal mode and operation is restarted in PWM mode 2 after re-setting.

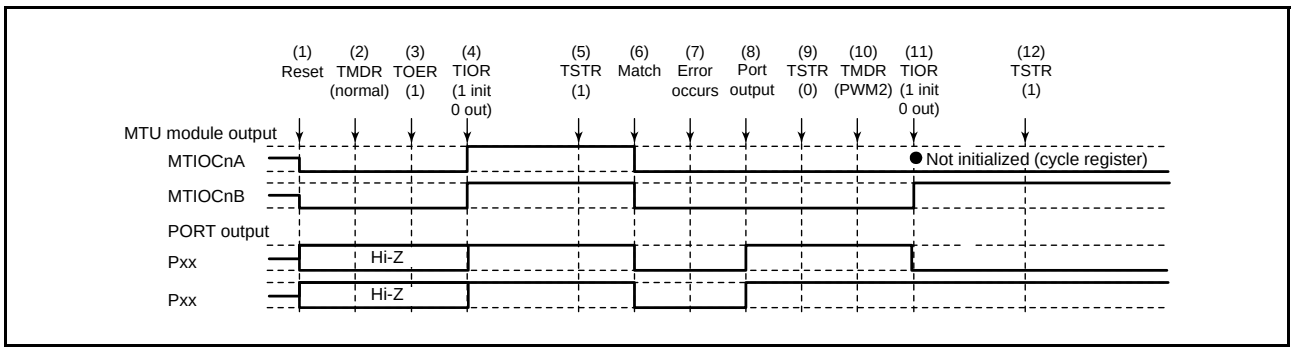


Figure 16.143 Error Occurrence in Normal Mode, Recovery in PWM Mode 2

(1) to (9) are the same as in Figure 16.141.
(10) Set PWM mode 2.
(11) Initialize the pins with TIOR. (In PWM mode 2, waveforms are not output to the cycle register pins. To output a specified level, make necessary settings for general output ports in the data direction registers (DDR) and data registers (DR) in the I/O ports.)
(12) Restart operation by setting TSTRA.

Note: • PWM mode 2 can only be selected for MTU0 to MTU2, and therefore TOERA setting is not necessary.

(4) Operation when Error Occurs in Normal Mode and Operation is Restarted in Phase Counting Mode

Figure 16.144 shows a case in which an error occurs in normal mode and operation is restarted in phase counting mode after re-setting.

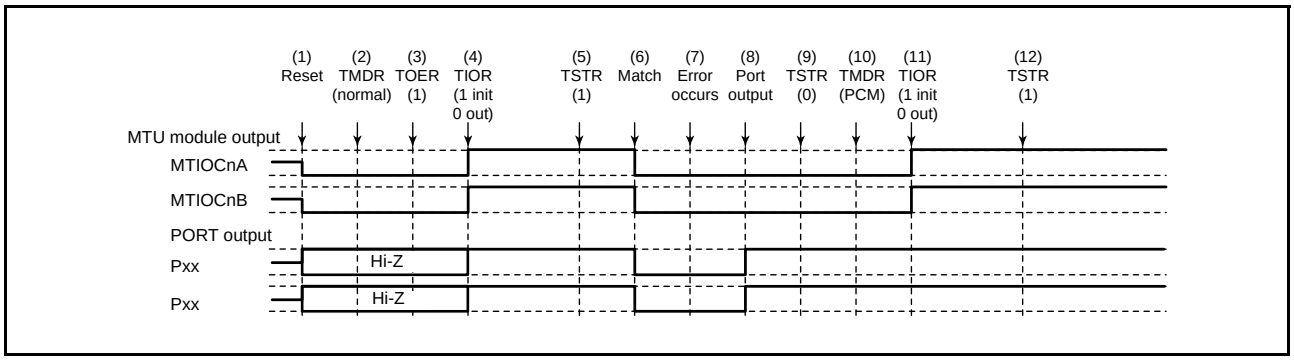


Figure 16.144 Error Occurrence in Normal Mode, Recovery in Phase Counting Mode

(1) to (9) are the same as in Figure 16.141.
(10) Set the phase counting mode.
(11) Initialize the pins with TIOR.
(12) Restart operation by setting TSTRA.

Note: • The phase counting mode can only be selected for MTU1 and MTU2, and therefore TOER setting is not necessary.

(5) Operation when Error Occurs in Normal Mode and Operation is Restarted in Complementary PWM Mode

Figure 16.145 shows a case in which an error occurs in normal mode and operation is restarted in complementary PWM mode after re-setting.

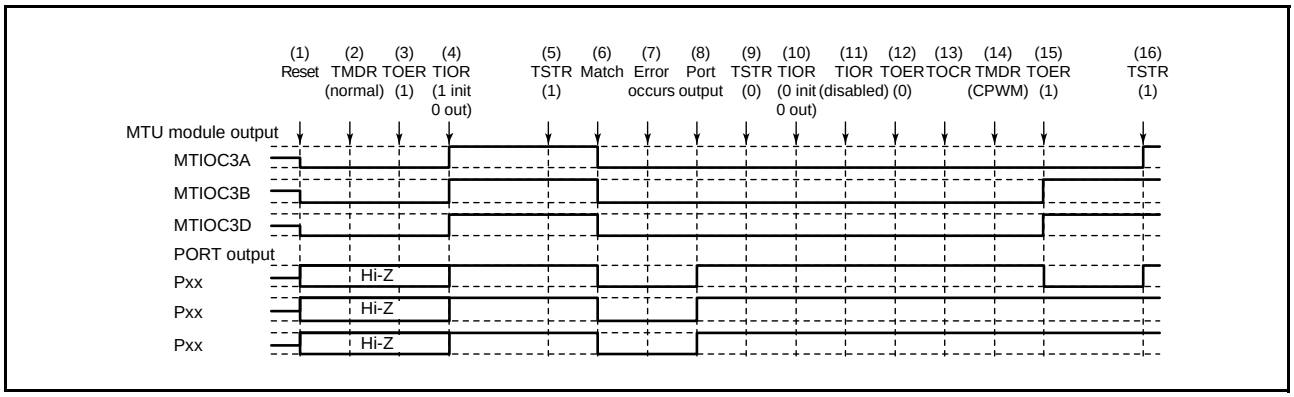


Figure 16.145 Error Occurrence in Normal Mode, Recovery in Complementary PWM Mode

(1) to (9) are the same as in Figure 16.141.
(10) Initialize the normal mode waveform generation section with TIOR.
(11) Disable operation of the normal mode waveform generation section with TIOR.
(12) Disable output in MTU3 and MTU4 with TOERA.
(13) Select the complementary PWM output level and enable or disable cyclic output with TOCR1A and TOCR2A.
(14) Set complementary PWM mode.
(15) Enable output in MTU3 and MTU4 with TOERA.
(16) Restart operation by setting TSTRA.

(6) Operation when Error Occurs in Normal Mode and Operation is Restarted in Reset-Synchronized PWM Mode

Figure 16.146 shows a case in which an error occurs in normal mode and operation is restarted in reset-synchronized PWM mode after re-setting.

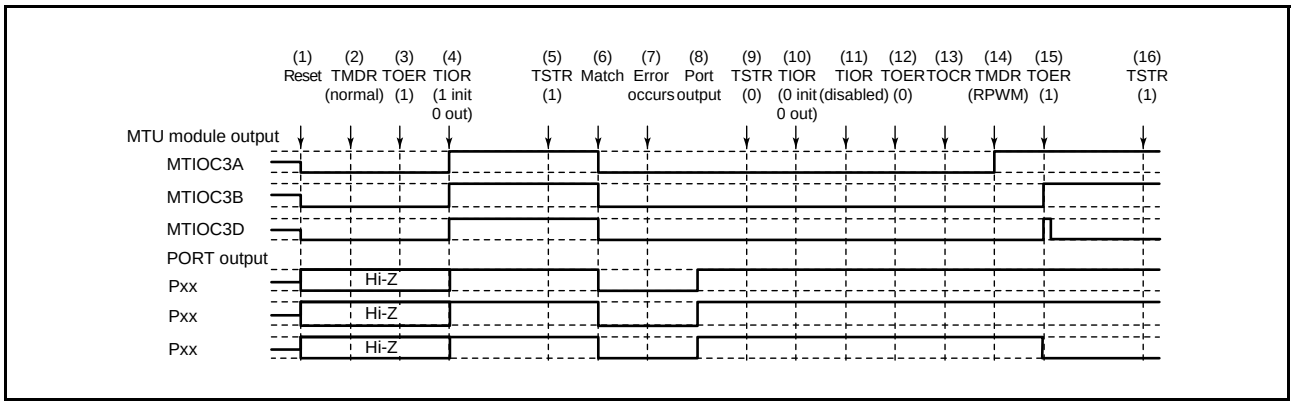


Figure 16.146 Error Occurrence in Normal Mode, Recovery in Reset-Synchronized PWM Mode

(1) to (12) are the same as in Figure 16.141.
(13) Select the reset-synchronized PWM output level and enable or disable cyclic output with TOCR1A and TOCR2A.
(14) Set reset-synchronized PWM mode.
(15) Enable output in MTU3 and MTU4 with TOERA.
(16) Restart operation by setting TSTRA.

(7) Operation when Error Occurs in PWM Mode 1 and Operation is Restarted in Normal Mode

Figure 16.147 shows a case in which an error occurs in PWM mode 1 and operation is restarted in normal mode after re-setting.

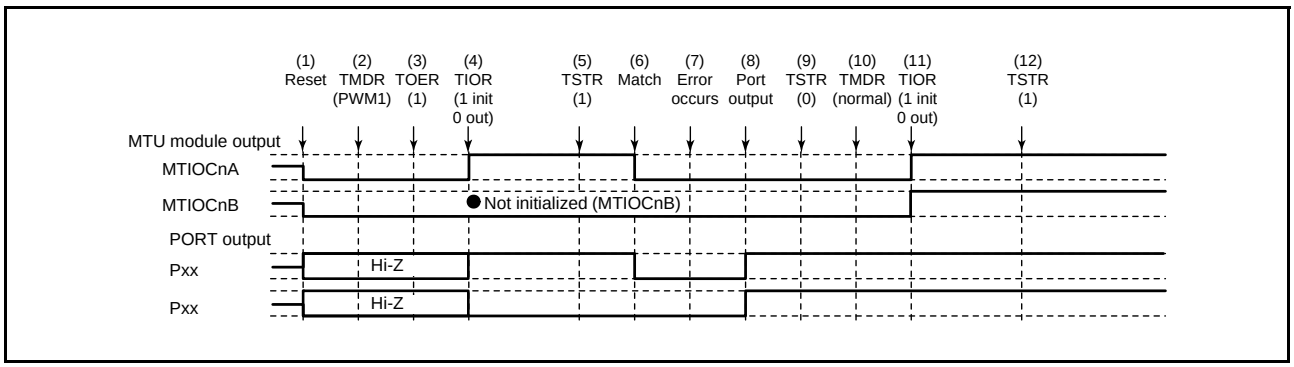


Figure 16.147 Error Occurrence in PWM Mode 1, Recovery in Normal Mode

(1) After a reset, the MTU3 output goes low and the ports enter high-impedance state.
(2) Set PWM mode 1.
(3) For MTU3 and MTU4, enable output with TOERA before initializing the pins with TIOR.
In addition, make necessary settings in the data direction registers (DDR) and data registers (DR) in the I/O ports so that a non-active level is output from the general ports.
(4) Initialize the pins with TIOR. (In the example, the initial output is a high level, and a low level is output on compare match occurrence. In PWM mode 1, the MTIOCnB side is not initialized.)
(5) Start count operation by setting TSTRA.
(6) Output goes low on compare match occurrence.
(7) An error occurs.
(8) Disable the MTU3 output with TIOR to switch the pins to general output ports so that a non-active level is output from the pins.
(9) Stop count operation by setting TSTRA.
(10) Set normal mode.
(11) Initialize the pins with TIOR.
(12) Restart operation by setting TSTRA.

(8) Operation when Error Occurs in PWM Mode 1 and Operation is Restarted in PWM mode 1

Figure 16.148 shows a case in which an error occurs in PWM mode 1 and operation is restarted in PWM mode 1 after re-setting.

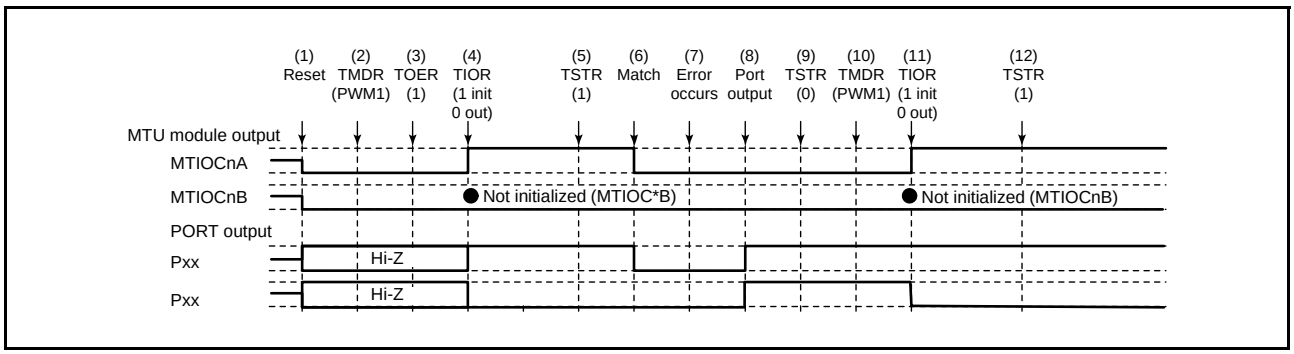


Figure 16.148 Error Occurrence in PWM Mode 1, Recovery in PWM Mode 1

(1) to (9) are the same as in Figure 16.147.
(10) This step is not necessary when restarting in PWM mode 1.
(11) Initialize the pins with TIOR. (In PWM mode 1, waveforms are not output to the MTIOCnB (MTIOCnD) pins. To output a specified level, make necessary settings for general output ports in the data direction registers (DDR) and data registers (DR) in the I/O ports.)
(12) Restart operation by setting TSTRA.

(9) Operation when Error Occurs in PWM Mode 1 and Operation is Restarted in PWM mode 2

Figure 16.149 shows a case in which an error occurs in PWM mode 1 and operation is restarted in PWM mode 2 after re-setting.

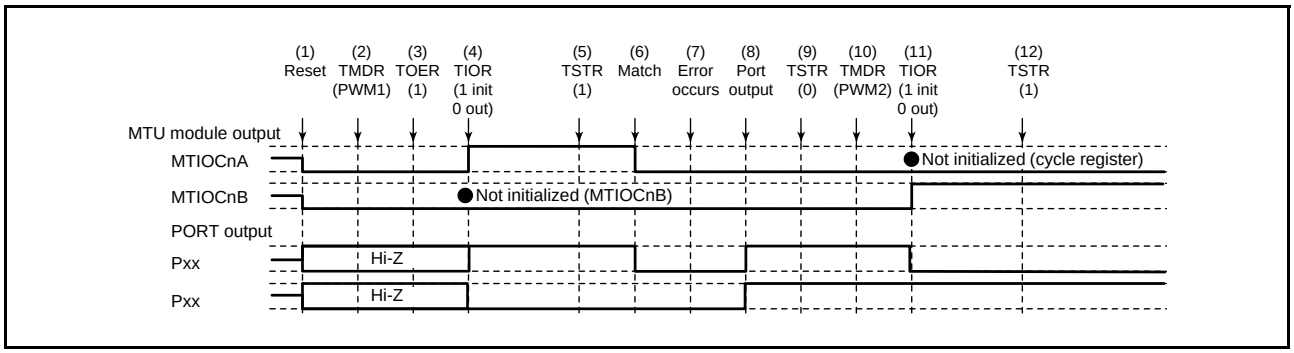


Figure 16.149 Error Occurrence in PWM Mode 1, Recovery in PWM Mode 2

(1) to (9) are the same as in Figure 16.147.
(10) Set PWM mode 2.
(11) Initialize the pins with TIOR. (In PWM mode 2, waveforms are not output to the cycle register pins. To output a specified level, make necessary settings for general output ports in the data direction registers (DDR) and data registers (DR) in the I/O ports.)
(12) Restart operation by setting TSTRA.

Note: • PWM mode 2 can only be selected for MTU0 to MTU2, and therefore TOERA setting is not necessary.

(10) Operation when Error Occurs in PWM Mode 1 and Operation is Restarted in Phase Counting Mode

Figure 16.150 shows a case in which an error occurs in PWM mode 1 and operation is restarted in phase counting mode after re-setting.

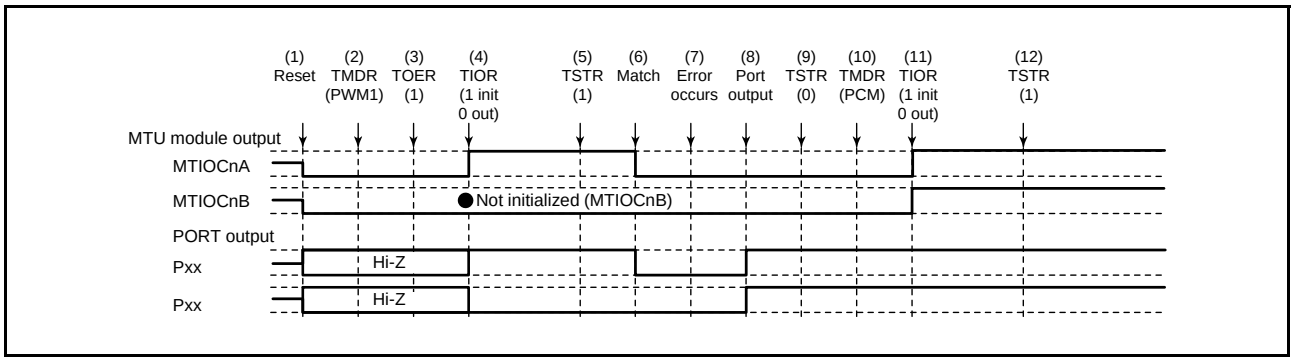


Figure 16.150 Error Occurrence in PWM Mode 1, Recovery in Phase Counting Mode

(1) to (9) are the same as in Figure 16.147.
(10) Set the phase counting mode.
(11) Initialize the pins with TIOR.
(12) Restart operation by setting TSTRA.

Note: • The phase counting mode can only be selected for MTU1 and MTU2, and therefore TOERA setting is not necessary.

(11) Operation when Error Occurs in PWM Mode 1 and Operation is Restarted in Complementary PWM Mode

Figure 16.151 shows a case in which an error occurs in PWM mode 1 and operation is restarted in complementary PWM mode after re-setting.

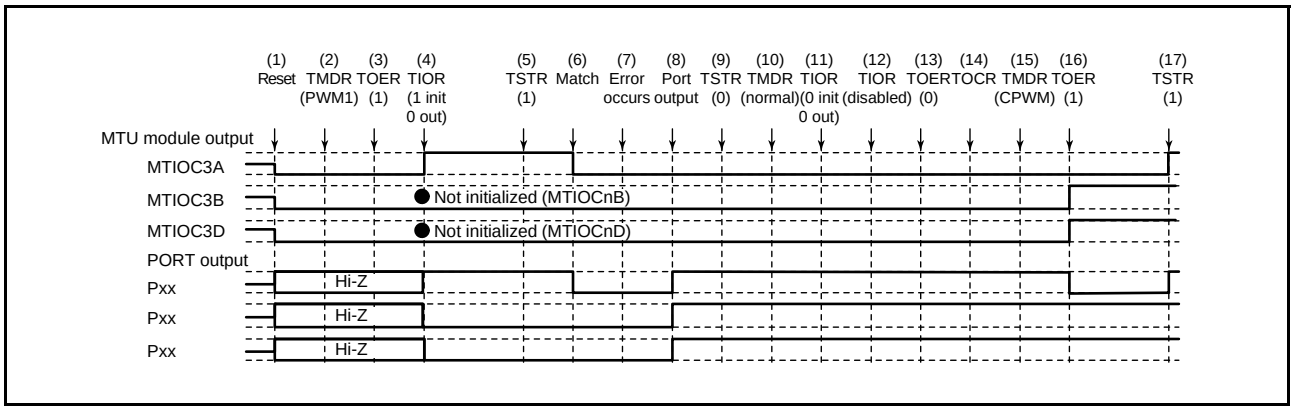


Figure 16.151 Error Occurrence in PWM Mode 1, Recovery in Complementary PWM Mode

(1) to (9) are the same as in Figure 16.147.
(10) Set normal mode to initialize the normal mode waveform generation section.
(11) Initialize the PWM mode 1 waveform generation section with TIOR.
(12) Disable operation of the PWM mode 1 waveform generation section with TIOR
(13) Disable output in MTU3 and MTU4 with TOERA.
(14) Select the complementary PWM output level and enable or disable cyclic output with TOCR1A and TOCR2A.
(15) Set complementary PWM mode.
(16) Enable output in MTU3 and MTU4 with TOERA.
(17) Restart operation by setting TSTRA.

(12) Operation when Error Occurs in PWM Mode 1 and Operation is Restarted in Reset-Synchronized PWM Mode

Figure 16.152 shows a case in which an error occurs in PWM mode 1 and operation is restarted in reset-synchronized PWM mode after re-setting.

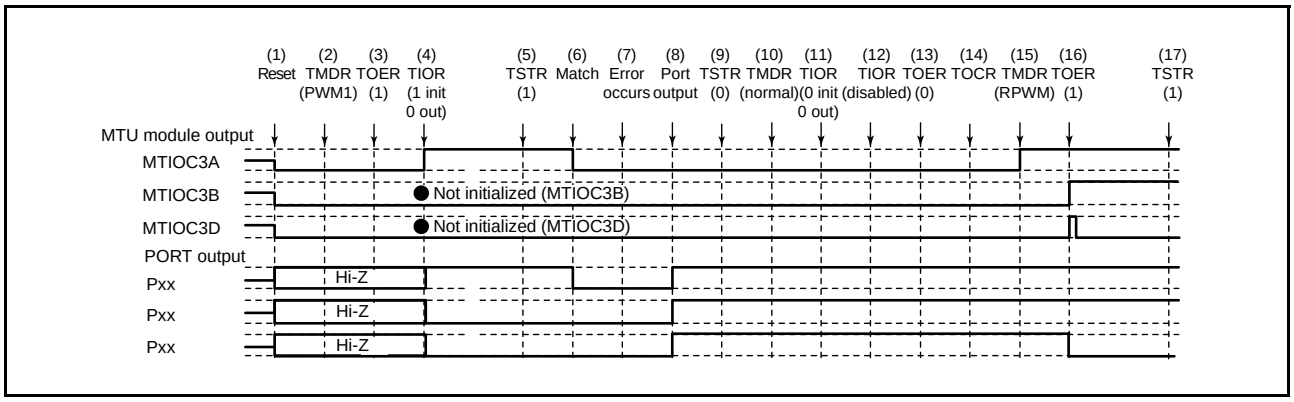


Figure 16.152 Error Occurrence in PWM Mode 1, Recovery in Reset-Synchronized PWM Mode

(1) to (13) are the same as in Figure 16.151.
(14) Select the reset-synchronized PWM output level and enable or disable cyclic output with TOCR1A and TOCR2A.
(15) Set reset-synchronized PWM mode.
(16) Enable output in MTU3 and MTU4 with TOERA.
(17) Restart operation by setting TSTRA.

(13) Operation when Error Occurs in PWM Mode 2 and Operation is Restarted in Normal Mode

Figure 16.153 shows a case in which an error occurs in PWM mode 2 and operation is restarted in normal mode after re-setting.

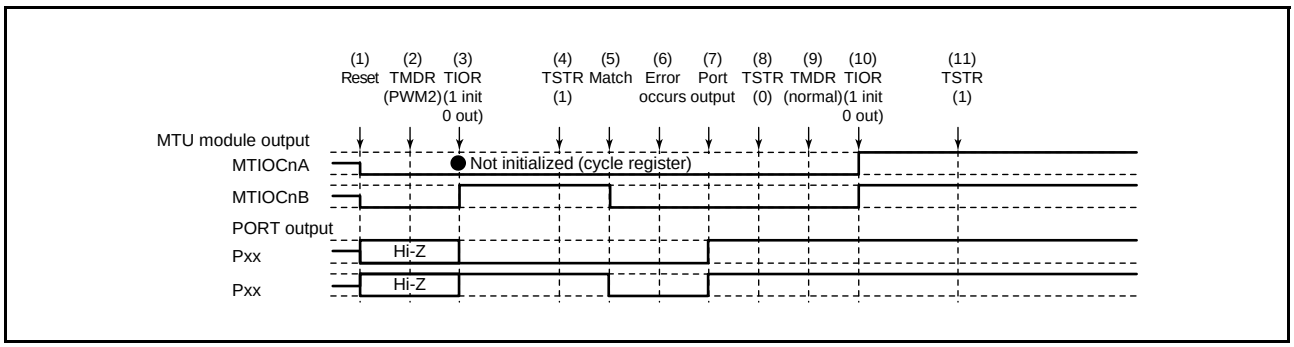


Figure 16.153 Error Occurrence in PWM Mode 2, Recovery in Normal Mode

(1) After a reset, the MTU3 output goes low and the ports enter high-impedance state.
(2) Set PWM mode 2.
In addition, make necessary settings in the data direction registers (DDR) and data registers (DR) in the I/O ports so that a non-active level is output from the general ports.
(3) Initialize the pins with TIOR. (In the example, the initial output is a high level, and a low level is output on compare match occurrence. In PWM mode 2, the cycle register pins are not initialized. In the example, MTIOCnA is the cycle register.)
(4) Start count operation by setting TSTRA.
(5) Output goes low on compare match occurrence.
(6) An error occurs.
(7) Disable the MTU3 output with TIOR to switch the pins to general output ports so that a non-active level is output from the pins.
(8) Stop count operation by setting TSTRA.
(9) Set normal mode.
(10) Initialize the pins with TIOR.
(11) Restart operation by setting TSTRA.

(14) Operation when Error Occurs in PWM Mode 2 and Operation is Restarted in PWM Mode 1

Figure 16.154 shows a case in which an error occurs in PWM mode 2 and operation is restarted in PWM mode 1 after re-setting.

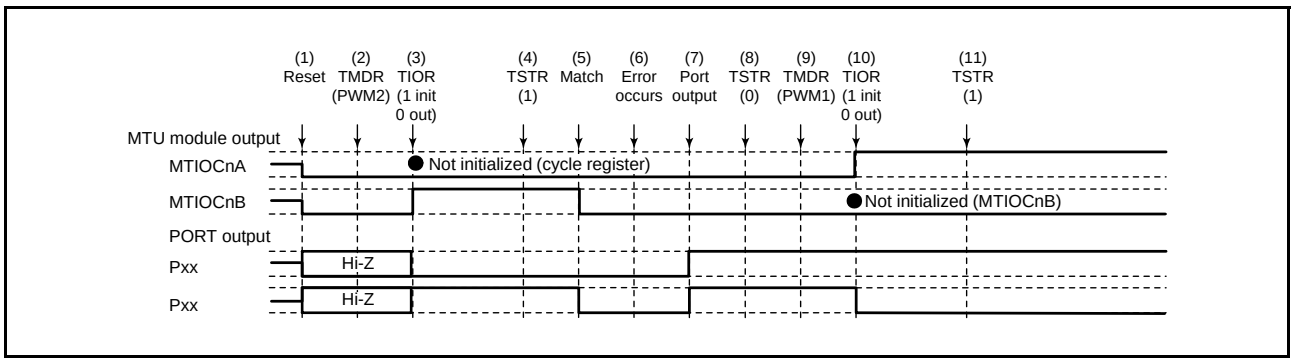


Figure 16.154 Error Occurrence in PWM Mode 2, Recovery in PWM Mode 1

(1) to (8) are the same as in Figure 16.153.
(9) Set PWM mode 1.
(10) Initialize the pins with TIOR. (In PWM mode 1, waveforms are not output to the MTIOCnB (MTIOCnD) pins. To output a specified level, make necessary settings for general output ports in the data direction registers (DDR) and data registers (DR) in the I/O ports.)
(11) Restart operation by setting TSTRA.

(15) Operation when Error Occurs in PWM Mode 2 and Operation is Restarted in PWM Mode 2

Figure 16.155 shows a case in which an error occurs in PWM mode 2 and operation is restarted in PWM mode 2 after re-setting.

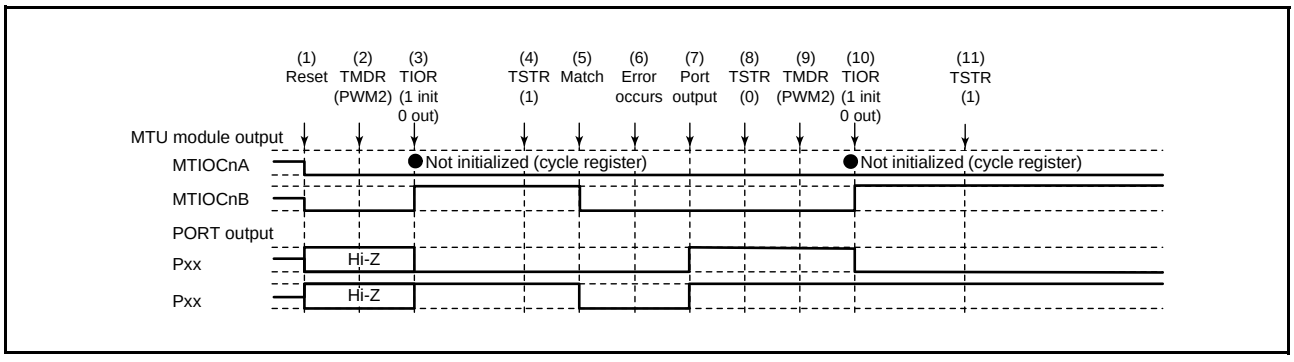


Figure 16.155 Error Occurrence in PWM Mode 2, Recovery in PWM Mode 2

(1) to (8) are the same as in Figure 16.153.
(9) This step is not necessary when restarting in PWM mode 2.
(10) Initialize the pins with TIOR. (In PWM mode 2, waveforms are not output to the cycle register pins. To output a specified level, make necessary settings for general output ports in the data direction registers (DDR) and data registers (DR) in the I/O ports.)
(11) Restart operation by setting TSTRA.

(16) Operation when Error Occurs in PWM Mode 2 and Operation is Restarted in Phase Counting Mode

Figure 16.156 shows a case in which an error occurs in PWM mode 2 and operation is restarted in phase counting mode after re-setting.

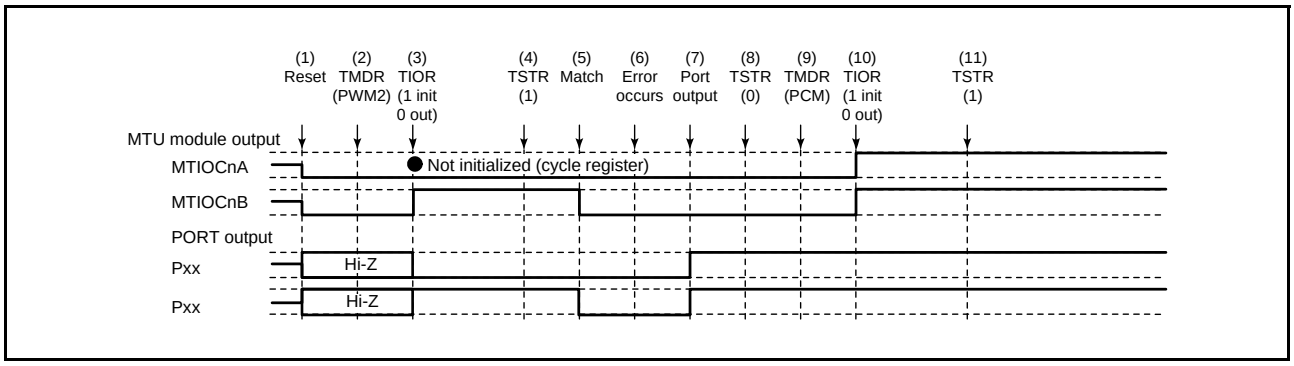


Figure 16.156 Error Occurrence in PWM Mode 2, Recovery in Phase Counting Mode

(1) to (8) are the same as in Figure 16.153.
(9) Set the phase counting mode.
(10) Initialize the pins with TIOR.
(11) Restart operation by setting TSTRA.

(17) Operation when Error Occurs in Phase Counting Mode and Operation is Restarted in Normal Mode

Figure 16.157 shows a case in which an error occurs in phase counting mode and operation is restarted in normal mode after re-setting.

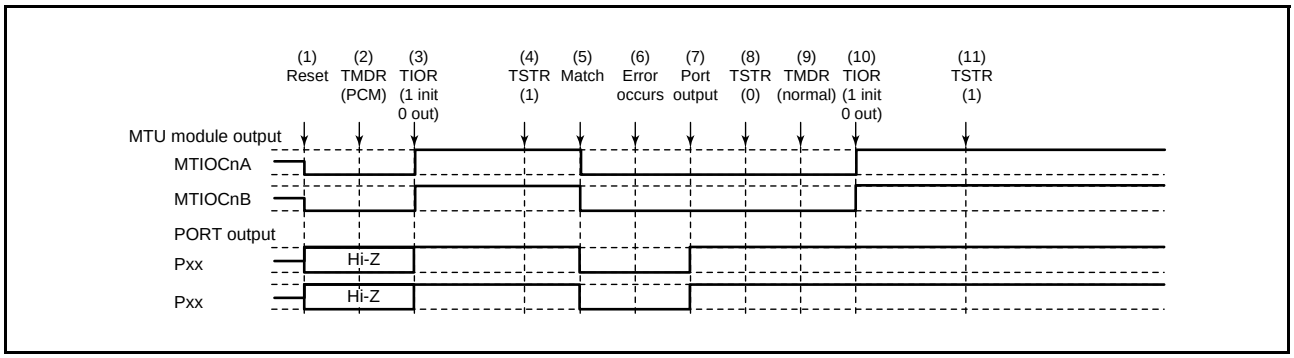


Figure 16.157 Error Occurrence in Phase Counting Mode, Recovery in Normal Mode

(1) After a reset, the MTU3 output goes low and the ports enter high-impedance state.
(2) Set phase counting mode.
In addition, make necessary settings in the data direction registers (DDR) and data registers (DR) in the I/O ports so that a non-active level is output from the general ports.
(3) Initialize the pins with TIOR. (In the example, the initial output is a high level, and a low level is output on compare match occurrence.)
(4) Start count operation by setting TSTRA.
(5) Output goes low on compare match occurrence.
(6) An error occurs.
(7) Disable the MTU3 output with TIOR to switch the pins to general output ports so that a non-active level is output from the pins.
(8) Stop count operation by setting TSTRA.
(9) Set normal mode.
(10) Initialize the pins with TIOR.
(11) Restart operation by setting TSTRA.

(18) Operation when Error Occurs in Phase Counting Mode and Operation is Restarted in PWM Mode 1

Figure 16.158 shows a case in which an error occurs in phase counting mode and operation is restarted in PWM mode 1 after re-setting.

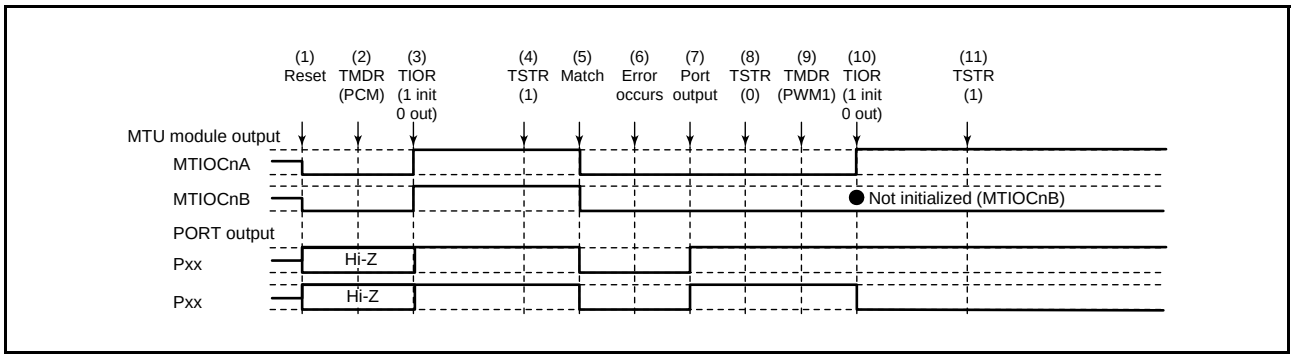


Figure 16.158 Error Occurrence in Phase Counting Mode, Recovery in PWM Mode 1

(1) to (8) are the same as in Figure 16.157.
(9) Set PWM mode 1.
(10) Initialize the pins with TIOR. (In PWM mode 1, waveforms are not output to the MTIOCnB (MTIOCnD) pins. To output a specified level, make necessary settings for general output ports in the data direction registers (DDR) and data registers (DR) in the I/O ports.)
(11) Restart operation by setting TSTRA.

(19) Operation when Error Occurs in Phase Counting Mode and Operation is Restarted in PWM Mode 2

Figure 16.159 shows a case in which an error occurs in phase counting mode and operation is restarted in PWM mode 2 after re-setting.

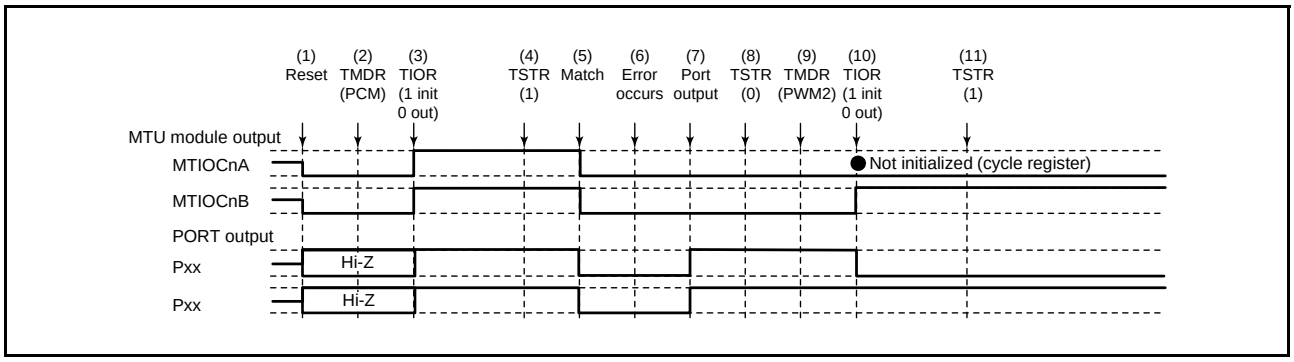


Figure 16.159 Error Occurrence in Phase Counting Mode, Recovery in PWM Mode 2

(1) to (8) are the same as in Figure 16.157.
(9) Set PWM mode 2.
(10) Initialize the pins with TIOR. (In PWM mode 2, waveforms are not output to the cycle register pins. To output a specified level, make necessary settings for general output ports in the data direction registers (DDR) and data registers (DR) in the I/O ports.)
(11) Restart operation by setting TSTRA.

(20) Operation when Error Occurs in Phase Counting Mode and Operation is Restarted in Phase Counting Mode

Figure 16.160 shows a case in which an error occurs in phase counting mode and operation is restarted in phase counting mode after re-setting.

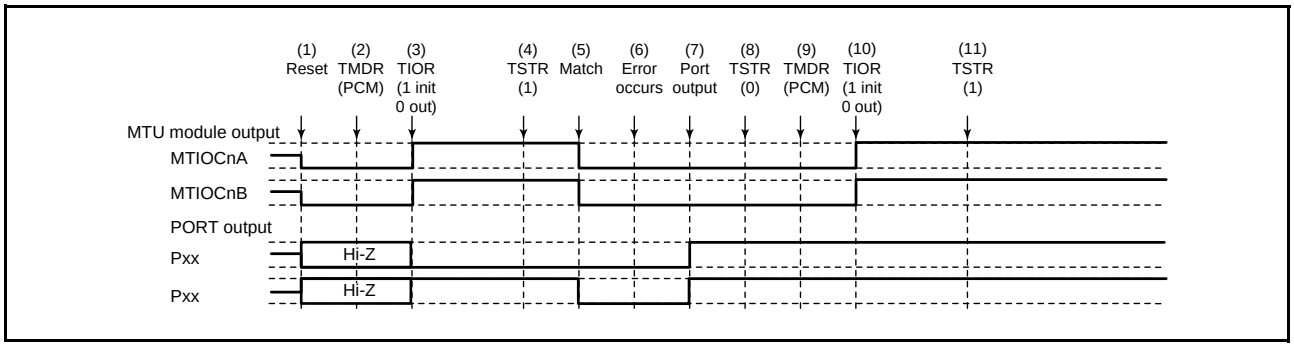


Figure 16.160 Error Occurrence in Phase Counting Mode, Recovery in Phase Counting Mode

(1) to (8) are the same as in Figure 16.157.
(9) This step is not necessary when restarting in phase counting mode.
(10) Initialize the pins with TIOR.
(11) Restart operation by setting TSTRA.

(21) Operation when Error Occurs in Complementary PWM Mode and Operation is Restarted in Normal Mode

Figure 16.161 shows a case in which an error occurs in complementary PWM mode and operation is restarted in normal mode after re-setting.

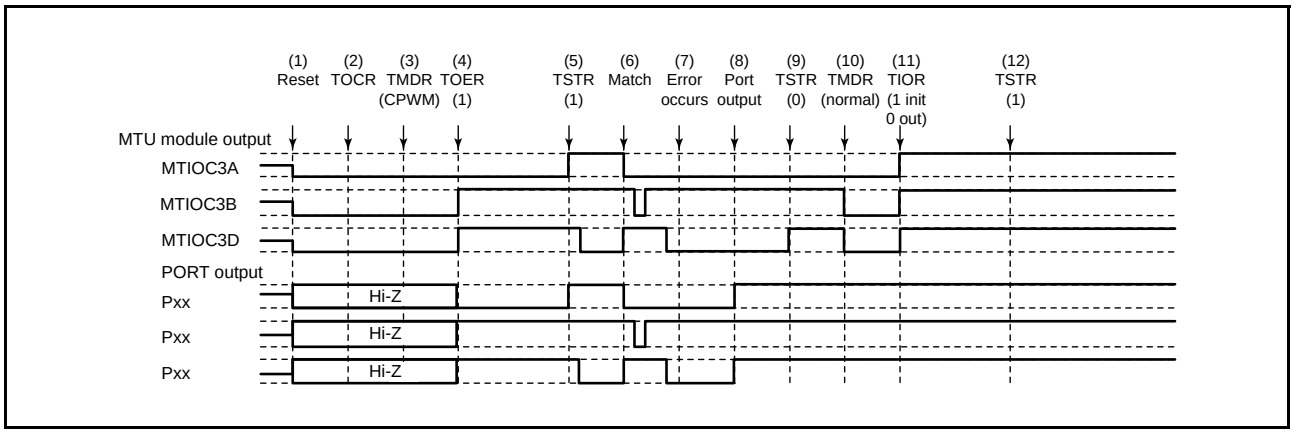


Figure 16.161 Error Occurrence in Complementary PWM Mode, Recovery in Normal Mode

(1) After a reset, the MTU3 output goes low and the ports enter high-impedance state.
(2) Select the complementary PWM output level and enable or disable cyclic output with TOCR1A and TOCR2A.
(3) Set complementary PWM mode.
In addition, make necessary settings in the data direction registers (DDR) and data registers (DR) in the I/O ports so that a non-active level is output from the general ports.
(4) Enable output in MTU3 and MTU4 with TOERA.
(5) Start count operation by setting TSTRA.
(6) The complementary PWM waveform is output on compare match occurrence.
(7) An error occurs.
(8) Disable the MTU3 output with TIOR to switch the pins to general output ports so that a non-active level is output from the pins.
(9) Stop count operation by setting TSTRA. (MTU3 output becomes the initial complementary PWM output value).
(10) Set normal mode (MTU3 output goes low).
(11) Initialize the pins with TIOR.
(12) Restart operation by setting TSTRA.

(22) Operation when Error Occurs in Complementary PWM Mode and Operation is Restarted in PWM Mode 1

Figure 16.162 shows a case in which an error occurs in complementary PWM mode and operation is restarted in PWM mode 1 after re-setting.

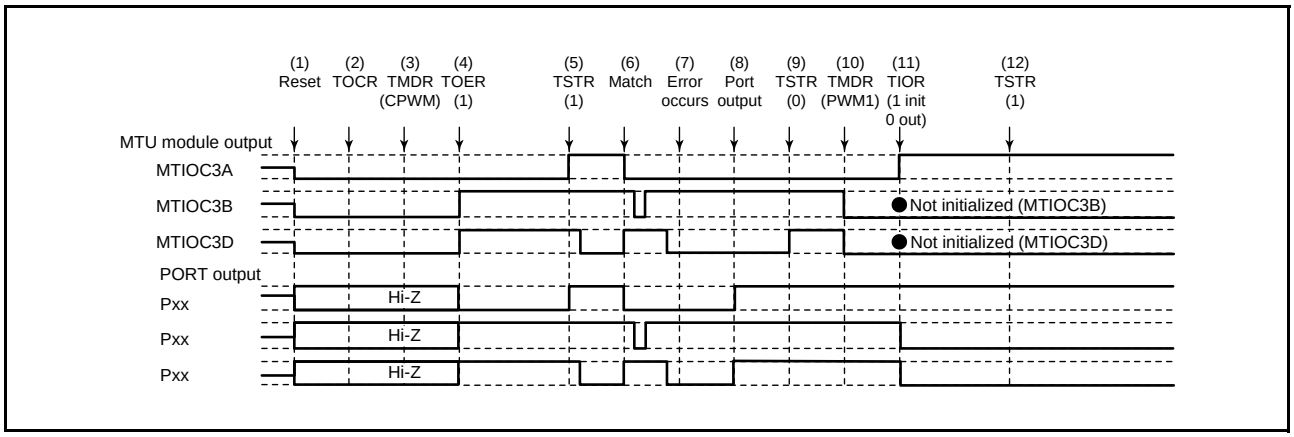


Figure 16.162 Error Occurrence in Complementary PWM Mode, Recovery in PWM Mode 1

(1) to (9) are the same as in Figure 16.161.
(10) Set PWM mode 1 (MTU3 output goes low).
(11) Initialize the pins with TIOR. (In PWM mode 1, waveforms are not output to the MTIOCnB (MTIOCnD) pins. To output a specified level, make necessary settings for general output ports in the data direction registers (DDR) and data registers (DR) in the I/O ports.)
(12) Restart operation by setting TSTRA.

(23) Operation when Error Occurs in Complementary PWM Mode and Operation is Restarted in Complementary PWM Mode

Figure 16.163 shows a case in which an error occurs in complementary PWM mode and operation is restarted in complementary PWM mode after re-setting (when operation is restarted using the cycle and duty settings at the time of stopping the counter).

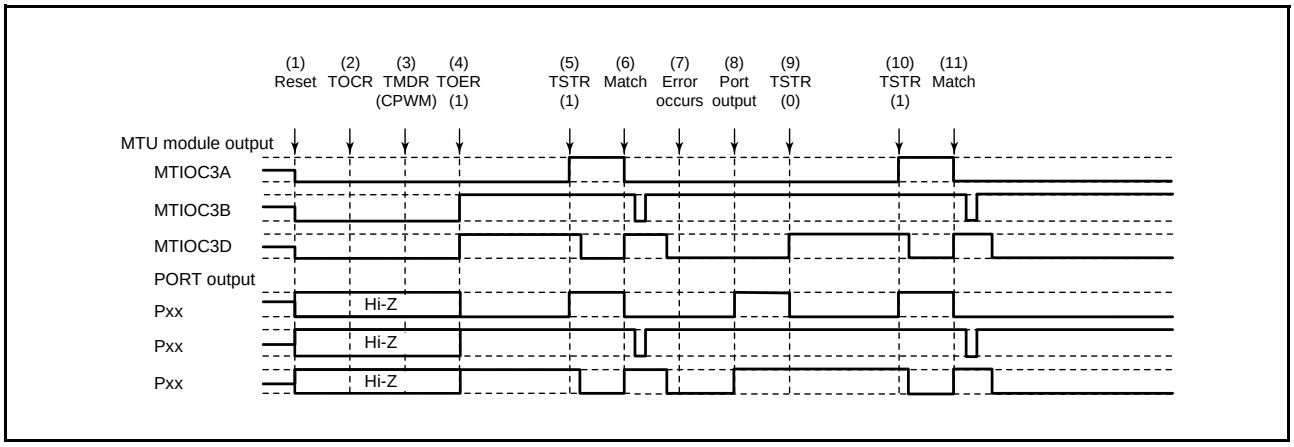


Figure 16.163 Error Occurrence in Complementary PWM Mode, Recovery in Complementary PWM Mode (1)

(1) to (9) are the same as in Figure 16.161.
(10) Restart operation by setting TSTRA.
(11) The complementary PWM waveform is output on compare match occurrence.

(24) Operation when Error Occurs in Complementary PWM Mode and Operation is Restarted in Complementary PWM Mode with New Settings

Figure 16.164 shows a case in which an error occurs in complementary PWM mode and operation is restarted in complementary PWM mode after re-setting (operation is restarted using new cycle and duty ratio settings).

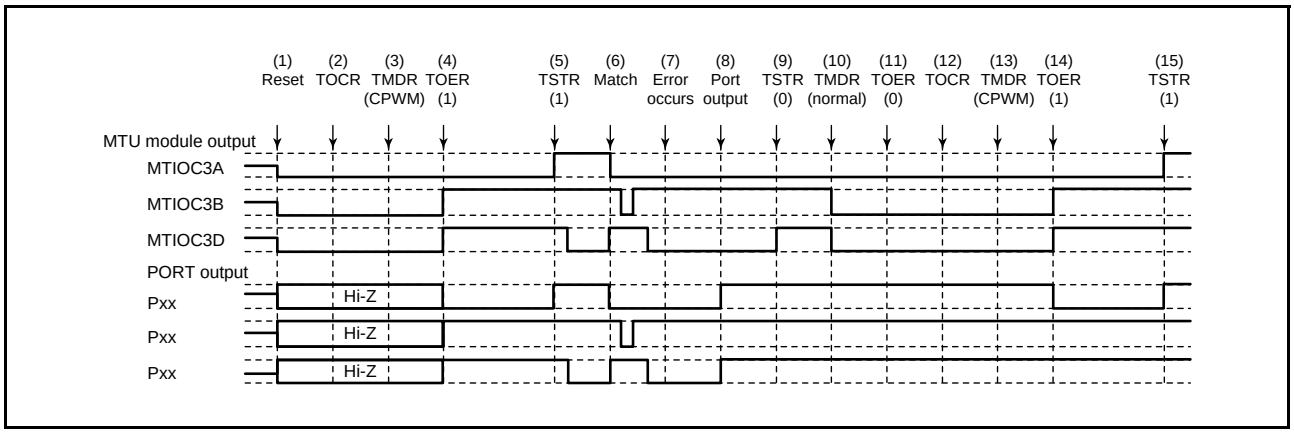


Figure 16.164 Error Occurrence in Complementary PWM Mode, Recovery in Complementary PWM Mode (2)

(1) to (9) are the same as in Figure 16.161.
(10) Set normal mode and make new settings (MTU3 output goes low).
(11) Disable output in MTU3 and MTU4 with TOERA.
(12) Select the complementary PWM output level and enable or disable cyclic output with TOCR1A and TOCR2A.
(13) Set complementary PWM mode.
(14) Enable output in MTU3 and MTU4 with TOERA.
(15) Restart operation by setting TSTRA.

(25) Operation when Error Occurs in Complementary PWM Mode and Operation is Restarted in Reset-Synchronized PWM Mode

Figure 16.165 shows a case in which an error occurs in complementary PWM mode and operation is restarted in reset-synchronized PWM mode after re-setting.

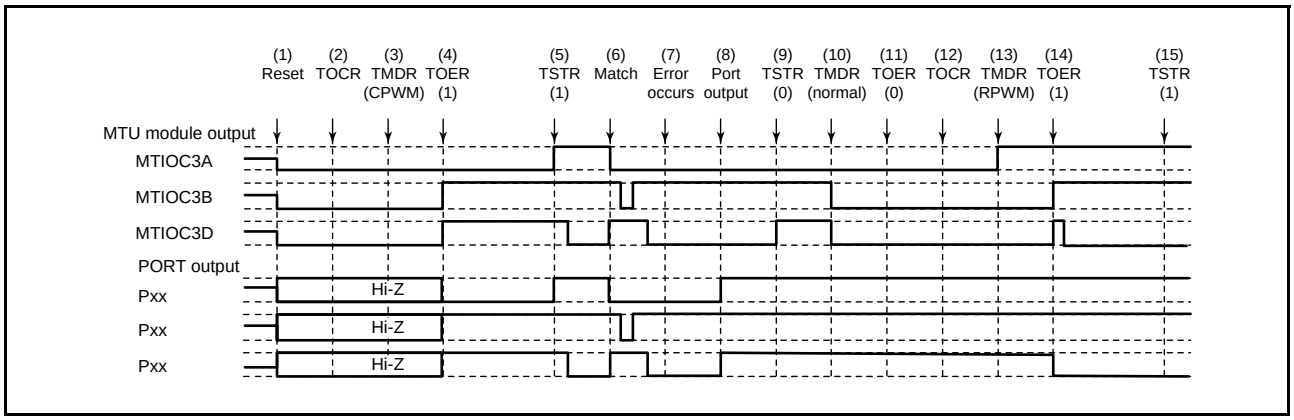


Figure 16.165 Error Occurrence in Complementary PWM Mode, Recovery in Reset-Synchronized PWM Mode

(1) to (9) are the same as in Figure 16.161.
(10) Set normal mode (MTU3 output goes low).
(11) Disable output in MTU3 and MTU4 with TOERA.
(12) Select the reset-synchronized PWM output level and enable or disable cyclic output with TOCR1A and TOCR2A.
(13) Set reset-synchronized PWM mode.
(14) Enable output in MTU3 and MTU4 with TOERA.
(15) Restart operation by setting TSTRA.

(26) Operation when Error Occurs in Reset-Synchronized PWM Mode and Operation is Restarted in Normal Mode

Figure 16.166 shows a case in which an error occurs in reset-synchronized PWM mode and operation is restarted in normal mode after re-setting.

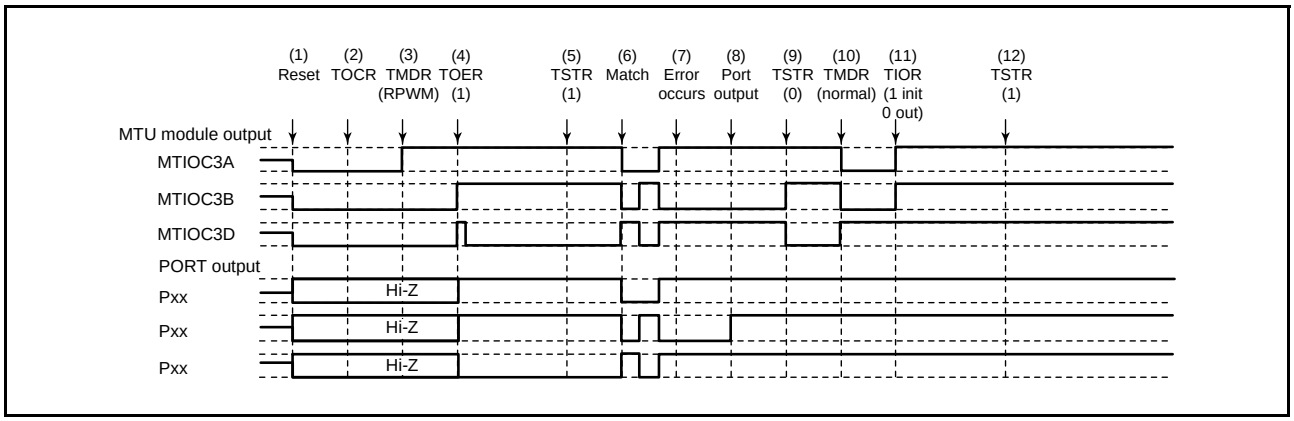


Figure 16.166 Error Occurrence in Reset-Synchronized PWM Mode, Recovery in Normal Mode

(1) After a reset, the MTU3 output goes low and the ports enter high-impedance state.
(2) Select the reset-synchronized PWM output level and enable or disable cyclic output with TOCR1A and TOCR2A.
(3) Set reset-synchronized PWM mode.
In addition, make necessary settings in the data direction registers (DDR) and data registers (DR) in the I/O ports so that a non-active level is output from the general ports.
(4) Enable output in MTU3 and MTU4 with TOERA.
(5) Start count operation by setting TSTRA.
(6) The reset-synchronized PWM waveform is output on compare match occurrence.
(7) An error occurs.
(8) Disable the MTU3 output with TIOR to switch the pins to general output ports so that a non-active level is output from the pins.
(9) Stop count operation by setting TSTRA. (MTU3 output becomes the initial reset-synchronized PWM output value.)
(10) Set normal mode (positive-phase MTU3 output goes low, and negative-phase output goes high).
(11) Initialize the pins with TIOR.
(12) Restart operation by setting TSTRA.

(27) Operation when Error Occurs in Reset-Synchronized PWM Mode and Operation is Restarted in PWM Mode 1

Figure 16.167 shows a case in which an error occurs in reset-synchronized PWM mode and operation is restarted in PWM mode 1 after re-setting.

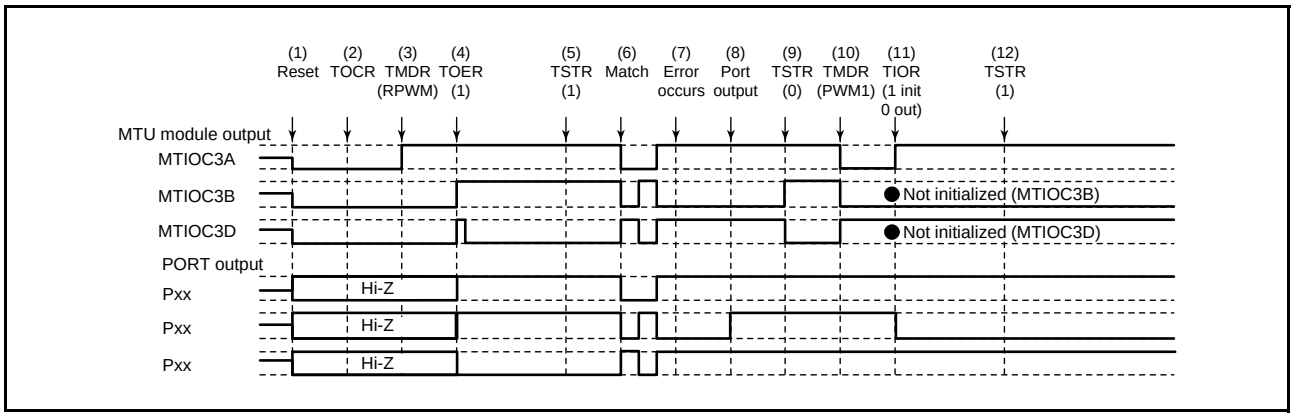


Figure 16.167 Error Occurrence in Reset-Synchronized PWM Mode, Recovery in PWM Mode 1

(1) to (9) are the same as in Figure 16.166.
(10) Set PWM mode 1 (positive-phase MTU3 output goes low, and negative-phase output goes high).
(11) Initialize the pins with TIOR. (In PWM mode 1, waveforms are not output to the MTIOCnB (MTIOCnD) pins. To output a specified level, make necessary settings for general output ports in the data direction registers (DDR) and data registers (DR) in the I/O ports.)
(12) Restart operation by setting TSTRA.

(28) Operation when Error Occurs in Reset-Synchronized PWM Mode and Operation is Restarted in Complementary PWM Mode

Figure 16.168 shows a case in which an error occurs in reset-synchronized PWM mode and operation is restarted in complementary PWM mode after re-setting.

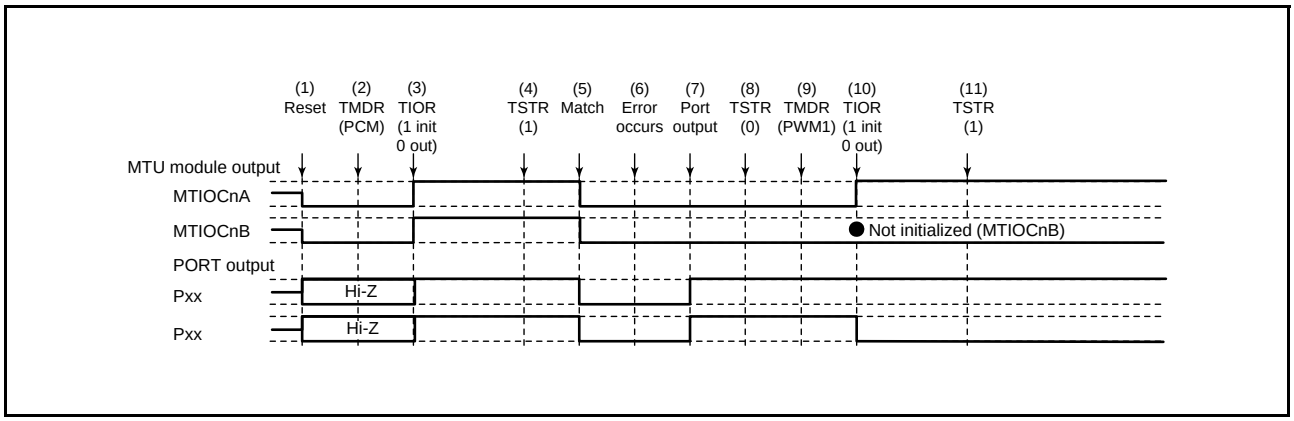


Figure 16.168 Error Occurrence in Reset-Synchronized PWM Mode, Recovery in Complementary PWM Mode

(1) to (9) are the same as in Figure 16.166.
(10) Disable output in MTU3 and MTU4 with TOERA.
(11) Select the complementary PWM output level and enable or disable cyclic output with TOCR1A and TOCR2A.
(12) Set complementary PWM mode (MTU3 cyclic output pin goes low).
(13) Enable output in MTU3 and MTU4 with TOERA.
(14) Restart operation by setting TSTRA.

(29) Operation when Error Occurs in Reset-Synchronized PWM Mode and Operation is Restarted in Reset-Synchronized PWM Mode

Figure 16.169 shows a case in which an error occurs in reset-synchronized PWM mode and operation is restarted in reset-synchronized PWM mode after re-setting.

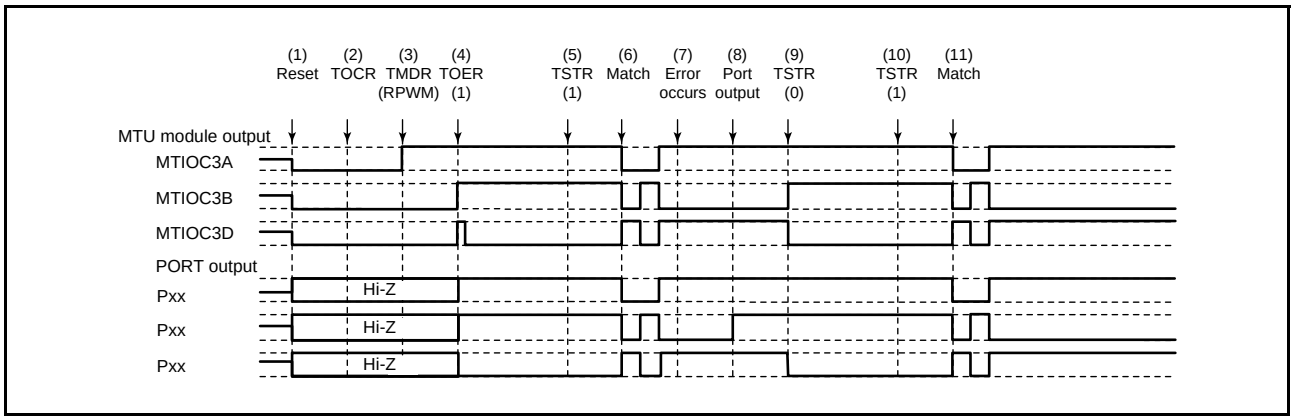


Figure 16.169 Error Occurrence in Reset-Synchronized PWM Mode, Recovery in Reset-Synchronized PWM Mode

(1) to (9) are the same as in Figure 16.166.
(10) Restart operation by setting TSTRA.
(11) The reset-synchronized PWM waveform is output on compare match occurrence.

17. Port Output Enable 3 (POE3)

The port output enable 3 (POE3) register can be used to place complementary PWM output pins for the MTU (MTIOC3B, MTIOC3D, MTIOC4A, MTIOC4B, MTIOC4C, MTIOC4D, MTIOC6B, MTIOC6D, MTIOC7A, MTIOC7B, MTIOC7C, and MTIOC7D) and large-current output pins for the GPT (GTIOC0A-A, GTIOC0B-A, GTIOC1A-A, GTIOC1B-A, GTIOC2A-A, and GTIOC2B-A) in the high-impedance state in accord with changes in the input signals on the POE0#, POE4#, POE8#, POE10#, and POE11# pins, and to place pin functions multiplexed with complementary PWM output pins for the MTU, pins for MTU0 (MTIOC0A, MTIOC0B, MTIOC0C, and MTIOC0D), and pins for the GPT (GTIOC0A, GTIOC0B, GTIOC1A, GTIOC1B, GTIOC2A, GTIOC2B, GTIOC3A, and GTIOC3B) in the high-impedance state in accord with register settings. It can also simultaneously generate interrupt requests. Furthermore, it is capable of placing pin functions multiplexed with complementary PWM output pins for the MTU, pins for MTU0, and pins for the GPT in the high-impedance state in response to stoppage of the clock signal from the clock oscillator.

17.1 Overview

Table 17.1 lists the specifications of the POE3, and Figure 17.1 shows a block diagram of the POE3.

Table 17.1 POE3 Specifications

Item	Description
Function	• Each of the POE0#, POE4#, POE8#, POE10#, and POE11# input pins can be set for falling edge, PCLK/8 × 16, PCLK/16 × 16, or PCLK/128 × 16 low-level sampling. • Pins for the MTU complementary PWM output, MTU0 to MTU3 and GPT pins can be placed in high-impedance state by POE0#, POE4#, POE8#, POE10#, and POE11# pin falling-edge or low-level sampling. • Pins for the MTU complementary PWM output, MTU0 to MTU3, and GPT pins can be placed in high-impedance state when the oscillation-stop detection circuit in the clock pulse generator detects stopped oscillation. • Pins for the MTU complementary PWM output can be placed in high-impedance state when output levels of the MTU complementary PWM output pins and the GPT large-current output pins are compared and simultaneous active-level output continues for one cycle or more. • Pins for the MTU complementary PWM output, and for MTU0 to MTU3 and the GPT, can be placed in the high-impedance state in response to comparator detection by the 12-bit A/D converter (S12ADA). • Pins for the MTU complementary PWM output, and for MTU0 to MTU3 and GPT pins can be placed in the high-impedance state by modifying settings of the POE registers. • Interrupts can be generated by input-level sampling or output-level comparison results.

The POE3 has input level detection circuits, output level comparison circuits, and a high-impedance request/interrupt request generating circuit as shown in Figure 17.1.

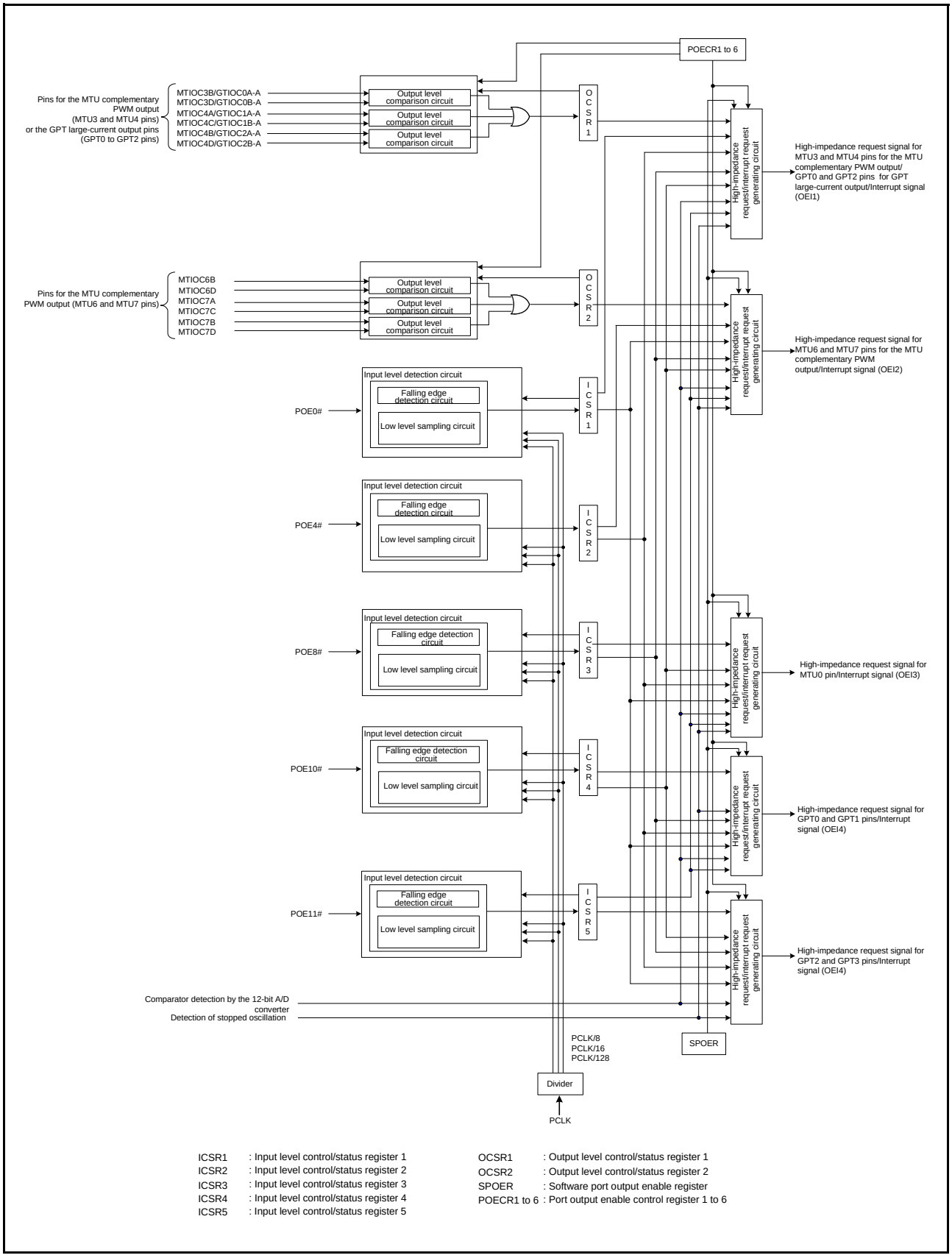


Figure 17.1 POE3 Block Diagram

Table 17.2 shows input/output pins to be used by the POE3.

Table 17.2 POE3 Input/Output Pins

Pin Name	I/O	Description
POE0#	Input	Request signal to place the MTU3 and MTU4 pins for MTU complementary PWM output in high-impedance state, and in accord with register settings, is also capable of placing the MTU6 and MTU7 pins for MTU complementary PWM output, MTU0 pins, and GPT pins in the high-impedance state.
POE4#	Input	Request signal to place the MTU6 and MTU7 pins for MTU complementary PWM output in high-impedance state, and in accord with register settings, is also capable of placing the MTU3 and MTU4 pins for MTU complementary PWM output, MTU0 pin, and GPT pins in high-impedance state.
POE8#	Input	Request signal to place the pins for MTU0 in high-impedance state, and in accord with register settings, is also capable of placing the MTU3, MTU4, MTU6, and MTU7 pins for MTU complementary PWM output, and GPT pins in high-impedance state.
POE10#	Input	Request signal to place the GPT0 and GPT1 pins in high-impedance state, and in accord with register settings, is also capable of placing the MTU3, MTU4, MTU6, and MTU7 pins for MTU complementary PWM output, MTU0 pin, and GPT2 and GPT3 pins in high-impedance state.
POE11#	Input	Request signal to place the pins for GPT2 and GPT3 in high-impedance state, and in accord with register settings, is also capable of placing the MTU3, MTU4 and MTU6, MTU7 pins for MTU complementary PWM output, MTU0 pin, and GPT0 and GPT1 pins in high-impedance state.

Table 17.3 shows output-level comparisons with pin combinations.

Table 17.3 Pin Combinations

Pin Combination	I/O	Description
MTIOC3B and MTIOC3D	Output	The MTU3 and MTU4 pins for MTU complementary PWM output are placed in high-impedance state when both pins of a pair simultaneously output the active level (low level when the OLSP bit in TOCR1A of MTUn is 0 with the TOCS bit in TOCR1A of MTUn cleared to 0 or high level when the OLSP bit is 1, or low level when the OLS3N, OLS3P, OLS2N, OLS2P, OLS1N, and OLS1P bits in TOCR2A of MTUn are 0 with the TOCS bit in TOCR1A of MTUn set to 1 and high level when these bits are 1) for one or more cycles of the peripheral clock (PCLK). Pin combinations for output comparison and high-impedance control can be selected by registers of POE3.
MTIOC4A and MTIOC4C	Output	
MTIOC4B and MTIOC4D	Output	
MTIOC6B and MTIOC6D	Output	The MTU6 and MTU7 pins for MTU complementary PWM output are placed in high-impedance state when both pins of a pair simultaneously output the active level (low level when the OLSP bit in TOCR1B of MTUn is 0 with the TOCS bit in TOCR1B of MTUn cleared to 0 or high level when the OLSP bit is 1, or low level when the OLS3N, OLS3P, OLS2N, OLS2P, OLS1N, and OLS1P bits in TOCR2B of MTUn are 0 with the TOCS bit in TOCR1B of MTUn set to 1 and high level when these bits are 1) for one or more cycles of the peripheral clock (PCLK). Pin combinations for output comparison and high-impedance control can be selected by registers of POE3.
MTIOC7A and MTIOC7C	Output	
MTIOC7B and MTIOC7D	Output	
GTIOC0A-A and GTIOC0B-A	Output	The GPT0 to GPT2 pins for the GPT large-current output are placed in high-impedance state when both pins of a pair simultaneously output the active level (low level when the OLSG2B, OLSG2A, OLSG1B, OLSG1A, OLSG0B, OLSG0A bits in ALR1 are 0 or high level when those bits are 1) for one or more cycles of the peripheral clock (PCLK). Pin combinations for output comparison and high-impedance control can be selected by registers of POE3.
GTIOC1A-A and GTIOC1B-A	Output	
GTIOC2A-A and GTIOC2B-A	Output	

17.2 Register Descriptions

Table 17.4 is the list of POE3 registers. The POE3 registers are initialized by a reset.

Table 17.4 POE3 Register Configuration

Register Name	Symbol	Value after Reset	Address	Access Size
Input level control/status register 1	ICSR1	0000h	0008 C4C0h	8, 16
Output level control/status register 1	OCSR1	0000h	0008 C4C2h	8, 16
Input level control/status register 2	ICSR2	0000h	0008 C4C4h	8, 16
Output level control/status register 2	OCSR2	0000h	0008 C4C6h	8, 16
Input level control/status register 3	ICSR3	0000h	0008 C4C8h	8, 16
Input level control/status register 4	ICSR4	0000h	0008 C4D6h	8, 16
Input level control/status register 5	ICSR5	0000h	0008 C4D8h	8, 16
Software port output enable register	SPOER	00h	0008 C4CAh	8
Port output enable control register 1	POECR1	00h	0008 C4CBh	8
Port output enable control register 2	POECR2	0707h	0008 C4CCh	16
Port output enable control register 3	POECR3	0303h	0008 C4CEh	16
Port output enable control register 4	POECR4	0402h	0008 C4D0h	16
Port output enable control register 5	POECR5	0008h	0008 C4D2h	16
Port output enable control register 6	POECR6	2010h	0008 C4D4h	16
Active level setting register 1	ALR1	0000h	0008 C4DAh	8,16

17.2.1 Input Level Control/Status Register 1 (ICSR1)

Address: 0008 C4C0h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	POE0F	—	—	—	PIE1	—	—	—	—	—	—	POE0M[1:0]	
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1, b0	POE0M[1:0]	POE0 Mode Select	b1 b0 0 0: Accepts a request on the falling edge of POE0# input. 0 1: Accepts a request when POE0# input has been sampled 16 times at PCLK/8 clock pulses and all are low level. 1 0: Accepts a request when POE0# input has been sampled 16 times at PCLK/16 clock pulses and all are low level. 1 1: Accepts a request when POE0# input has been sampled 16 times at PCLK/128 clock pulses and all are low level.	R/W*1
b7 to b2	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W
b8	PIE1	Port Interrupt Enable 1	0: Interrupt requests disabled 1: Interrupt requests enabled	R/W
b11 to b9	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W
b12	POE0F	POE0 Flag	0: Indicates that a high-impedance request has not been input to the POE0# pin. 1: Indicates that a high-impedance request has been input to the POE0# pin.	R/(W)*2
b13 to b15	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W

Note 1. Can be modified only once after a reset.
Note 2. Writing 0 to this bit after reading it as 1 clears the flag and is the only allowed way.

ICSR1 selects the input modes for the POE0# to POE3# pins, controls the enable/disable of interrupts, and indicates status.

POE0M[1:0] Bits (POE0 Mode Select)

These bits select the input mode of the POE0# pin.

PIE1 Bit (Port Interrupt Enable 1)

This bit enables or disables interrupt requests when any one of the POE0F bit of the ICSR1 is set to 1.

POE0F Flag (POE0 Flag)

This flag indicates that a high-impedance request has been input to the POE0# pin.
[Clearing conditions]

- By writing 0 to POE0F after reading POE0F = 1

[Setting condition]

- When the input set by POE0M[1:0] occurs at the POE0# pin

17.2.2 Output Level Control/Status Register 1 (OCSR1)

Address: 0008 C4C2h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	OSF1	—	—	—	—	—	OCE1	OIE1	—	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b7 to b0	—	Reserved	These bits are always read as 0. The write value should be 0.	RW
b8	OIE1	Output Short Interrupt Enable 1	0: Interrupt requests disabled. 1: Interrupt requests enabled.	R/W
b9	OCE1	Output Short High-Impedance Enable 1	0: Does not place the pins in high-impedance state. 1: Places the pins in high-impedance state.	R/W*1
b14 to b10	—	Reserved	These bits are always read as 0. The write value should be 0.	RW
b15	OSF1	Output Short Flag 1	0: Indicates that outputs have not simultaneously become an active level. 1: Indicates that outputs have simultaneously become an active level.	R/(W)*2

Note 1. Can be modified only once after a reset.
Note 2. Writing 0 to this bit after reading it as 1 clears the flag and is the only allowed way.

OCSR1 controls the enable/disable of output level comparison and interrupts, and indicates status.

OIE1 Bit (Output Short Interrupt Enable 1)

This bit enables or disables interrupt requests when the OSF1 bit in OCSR1 is set to 1.

OCE1 Bit (Output Short High-Impedance Enable 1)

This bit specifies whether to place the pins in high-impedance state when the OSF1 bit in OCSR1 is set to 1.

OSF1 Flag (Output Short Flag 1)

This flag indicates that any one of the three pairs of two-phase MTU3 and MTU4 pins for MTU complementary PWM output or GPT0 to GPT2 pins for the GPT large-current output to be compared has simultaneously become an active level.

[Clearing condition]

- By writing 0 to OSF1 after reading OSF1 = 1

[Setting condition]

- When any one of the three pairs of two-phase outputs has simultaneously become an active level

17.2.3 Active Level Setting Register 1 (ALR1)

Address: 0008 C4DAh

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	OLSEN	—	OLSG2B	OLSG2A	OLSG1B	OLSG1A	OLSG0B	OLSG0A
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	OLSG0A	MTIOC3B/GTIOC0A-A active level setting	0: Active low 1: Active high	R/W*
b1	OLSG0B	MTIOC3D/GTIOC0B-A active level setting	0: Active low 1: Active high	R/W*1
b2	OLSG1A	MTIOC4A/GTIOC1A-A active level setting	0: Active low 1: Active high	R/W*1
b3	OLSG1B	MTIOC4C/GTIOC1B-A active level setting	0: Active low 1: Active high	R/W*1
b4	OLSG2A	MTIOC4B/GTIOC2A-A active level setting	0: Active low 1: Active high	R/W*1
b5	OLSG2B	MTIOC4D/GTIOC2B-A active level setting	0: Active low 1: Active high	R/W*1
b6	—	Reserved	This bit is always read as 0. The write value should be 0.	R/W
b7	OLSEN	Active level setting enable	0: Disabled 1: Enabled	R/W*1
b15 to b8	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W

Note 1. Can be modified only once after a reset.

ALR1 specifies the active levels of the MTU3 and GPT outputs for detection of short circuits of those outputs as reflected in OCSR1.

OLSG0A bit (MTIOC3B/GTIOC0A-A Active Level Setting)

This bit sets the active level of the MTIOC3B and GTIOC0A-A outputs. Specifically, setting the OLSG0A bit to 0 sets the low level and to 1 sets the high level as the active level for detection of short circuits.

OLSG0B bit (MTIOC3D/GTIOC0B-A Active Level Setting)

This bit sets the active level of the MTIOC3D and GTIOC0B-A outputs. Specifically, setting the OLSG0B bit to 0 sets the low level and to 1 sets the high level as the active level for detection of short circuits.

OLSG1A bit (MTIOC4A/GTIOC1A-A Active Level Setting)

This bit sets the active level of the MTIOC4A and GTIOC1A-A outputs. Specifically, setting the OLSG1A bit to 0 sets the low level and to 1 sets the high level as the active level for detection of short circuits.

OLSG1B bit (MTIOC4C/GTIOC1B-A Active Level Setting)

This bit sets the active level of the MTIOC4C and GTIOC1B-A outputs. Specifically, setting the OLSG1B bit to 0 sets the low level and to 1 sets the high level as the active level for detection of short circuits.

OLSG2A bit (MTIOC4B/GTIOC2A-A Active Level Setting)

This bit sets the active level of the MTIOC4B and GTIOC2A-A outputs. Specifically, setting the OLSG2A bit to 0 sets the low level and to 1 sets the high level as the active level for detection of short circuits.

OLSG2B bit (MTIOC4D/GTIOC2B-A Active Level Setting)

This bit sets the active level of the MTIOC4D and GTIOC2B-A outputs. Specifically, setting the OLSG2B bit to 0 sets the low level and to 1 sets the high level as the active level for detection of short circuits.

OLSEN bit (Active Level Setting)

This bit selects enabling or disabling of the active-level settings in the OLSGnm bits (n is 0 to 2, m is A or B). Clearing the OLSEN bit to 0 disables the OLSGnm bits, in which case the active levels of the MTU3 output are as selected by the OLSGn bits in TOCR1 and TOCR2.

Setting the OLSEN bit to 1 enables the OLSGnm bits, in which case the active levels of the MTU3 output are as selected by the OLSGnm bits in this register.

Active levels for the GPT output can only be set when the OLSEN bit is 1. When output short-circuit detection is to be used on the GPT outputs, set the OLSEN bit to 1 and then use the OLSGnm bits to set the active levels for the GPT outputs.

17.2.4 Input Level Control/Status Register 2 (ICSR2)

Address: 0008 C4C4h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	POE4F	—	—	—	PIE2	—	—	—	—	—	—	POE4M[1:0]	
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1, b0	POE4M[1:0]	POE4 Mode Select	b1 b0 0 0: Accepts a request on the falling edge of POE4# input. 0 1: Accepts a request when POE4# input has been sampled 16 times at PCLK/8 clock pulses and all are low level. 1 0: Accepts a request when POE4# input has been sampled 16 times at PCLK/16 clock pulses and all are low level. 1 1: Accepts a request when POE4# input has been sampled 16 times at PCLK/128 clock pulses and all are low level.	R/W*1
b7 to b2	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W
b8	PIE2	Port Interrupt Enable 2	0: Interrupt requests disabled 1: Interrupt requests enabled	R/W
b11 to b9	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W
b12	POE4F	POE4 Flag	0: Indicates that a high-impedance request has not been input to the POE4# pin. 1: Indicates that a high-impedance request has been input to the POE4# pin.	R/(W)*2
b15 to b13	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W

Note 1. Can be modified only once after a reset.
Note 2. Writing 0 to this bit after reading it as 1 clears the flag and is the only allowed way.

ICSR2 selects the input modes for the POE4# pin, controls the enable/disable of interrupts, and indicates status.

POE4M[1:0] Bits (POE4 Mode Select)

These bits select the input mode of the POE4# pin.

PIE2 Bit (Port Interrupt Enable 2)

This bit enables/disables interrupt requests when the POE4F bit in ICSR2 is set to 1.

POE4F Flag (POE4 Flag)

This flag indicates that a high-impedance request has been input to the POE4# pin.
[Clearing conditions]

- By writing 0 to POE4F after reading POE4F = 1

[Setting condition]

- When the input set by POE4M[1:0] occurs at the POE4# pin

17.2.5 Output Level Control/Status Register 2 (OCSR2)

Address: 0008 C4C6h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	OSF2	—	—	—	—	—	OCE2	OIE2	—	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b7 to b0	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W
b8	OIE2	Output Short Interrupt Enable 2	0: Interrupt requests disabled. 1: Interrupt requests enabled.	R/W
b9	OCE2	Output Short High-Impedance Enable 2	0: Does not place the pins in high-impedance state. 1: Places the pins in high-impedance state.	R/W*1
b14 to b10	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W
b15	OSF2	Output Short Flag 2	0: Indicates that outputs have not simultaneously become an active level. 1: Indicates that outputs have simultaneously become an active level.	R/(W)*2

Note 1. Can be modified only once after a reset.
Note 2. Writing 0 to this bit after reading it as 1 clears the flag and is the only allowed way.

OCSR2 controls the enable/disable of output level comparison and interrupts, and indicates status.

OIE2 Bit (Output Short Interrupt Enable 2)

This bit enables or disables interrupt requests when the OSF2 bit in OCSR2 is set to 1.

OCE2 Bit (Output Short High-Impedance Enable 2)

This bit specifies whether to place the pins in high-impedance state when the OSF2 bit in OCSR2 is set to 1.

OSF2 Flag (Output Short Flag 2)

This flag indicates that any one of the three pairs of two-phase MTU6 and MTU7 pins for MTU complementary PWM output to be compared has simultaneously become an active level.

[Clearing condition]

- By writing 0 to OSF2 after reading OSF2 = 1

[Setting condition]

- When any one of the three pairs of two-phase outputs has simultaneously become an active level

17.2.6 Input Level Control/Status Register 3 (ICSR3)

Address: 0008 C4C8h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	POE8F	—	—	POE8E	PIE3	—	—	—	—	—	—	POE8M[1:0]	
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1, b0	POE8M[1:0]	POE8 Mode Select	b1 b0 00: Accepts a request on the falling edge of POE8# input 01: Accepts a request when POE8# input has been sampled 16 times at PCLK/8 clock pulses and all are low level. 10: Accepts a request when POE8# input has been sampled 16 times at PCLK/16 clock pulses and all are low level. 11: Accepts a request when POE8# input has been sampled 16 times at PCLK/128 clock pulses and all are low level.	R/W*1
b7 to b2	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W
b8	PIE3	Port Interrupt Enable 3	0: Interrupt requests disabled 1: Interrupt requests enabled	R/W
b9	POE8E	POE8 High-Impedance Enable	0: Does not place the pin in high-impedance state. 1: Places the pin in high-impedance state.	R/W*1
b11, b10	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W
b12	POE8F	POE8 Flag	0: Indicates that a high-impedance request has not been input to the POE8# pin. 1: Indicates that a high-impedance request has been input to the POE8# pin.	R/(W)*2
b15 to b13	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W

Note 1. Can be modified only once after a reset.
Note 2. Writing 0 to this bit after reading it as 1 clears the flag and is the only allowed way.

ICSR3 selects the input mode for the POE8# pin, controls the enable/disable of interrupts, and indicates status.

POE8M[1:0] Bits (POE8 Mode Select)

These bits select the input mode of the POE8# pin.

PIE3 Bit (Port Interrupt Enable 3)

This bit enables or disables interrupt requests when the POE8F bit in ICSR3 is set to 1.

POE8E Bit (POE8 High-Impedance Enable)

This bit specifies whether to place the corresponding pin in high-impedance state when the POE8F bit is set to 1.

POE8F Flag (POE8 Flag)

This flag indicates that a high-impedance request has been input to the POE8# pin.
[Clearing condition]

- By writing 0 to POE8F after reading POE8F = 1

[Setting condition]

- When the input set by POE8M[1:0] occurs at the POE8# pin

17.2.7 Input Level Control/Status Register 4 (ICSR4)

Address: 0008 C4D6h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	POE10F	—	—	POE10E	PIE4	—	—	—	—	—	—	POE10M[1:0]	
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1, b0	POE10M[1:0]	POE10 Mode Select	b1 b0 00: Accepts a request on the falling edge of POE10# input 01: Accepts a request when POE10# input has been sampled 16 times at PCLK/8 clock pulses and all are low level. 10: Accepts a request when POE10# input has been sampled 16 times at PCLK/16 clock pulses and all are low level. 11: Accepts a request when POE10# input has been sampled 16 times at PCLK/128 clock pulses and all are low level.	R/W*1
b7 to b2	—	Reserved	These bits are always read as 0. The write value should be 0.	RW
b8	PIE4	Port Interrupt Enable 4	0: Interrupt requests disabled. 1: Interrupt requests enabled.	R/W
b9	POE10E	POE10 High-Impedance Enable	0: Does not place the pin in high-impedance state. 1: Places the pin in high-impedance state.	R/W*1
b11, b10	—	Reserved	These bits are always read as 0. The write value should be 0.	RW
b12	POE10F	POE10 Flag	0: Indicates that a high-impedance request has not been input to the POE10# pin. 1: Indicates that a high-impedance request has been input to the POE10# pin.	R/(W)*2
b15 to b13	—	Reserved	These bits are always read as 0. The write value should be 0.	RW

Note 1. Can be modified only once after a reset.
Note 2. Writing 0 to this bit after reading it as 1 clears the flag and is the only allowed way.

ICSR4 selects the POE10# pin input mode, controls the enable/disable of interrupts, and indicates status.

POE10M[1:0] Bits (POE10 Mode Select)

These bits select the input mode of the POE10# pin.

PIE4 Bit (Port Interrupt Enable 4)

This bit enables or disables interrupt requests when the POE10F bit is set to 1.

POE10E Bit (POE10 High-Impedance Enable)

This bit specifies whether to place the corresponding pin in high-impedance state when the POE10F bit is set to 1.

POE10F Bit (POE10 Flag)

This flag indicates that a request for the high-impedance state has been input to the POE10# pin.
[Clearing condition]

- By writing 0 to POE10F after reading POE10F = 1

[Setting condition]

- When the input set by POE10M[1:0] occurs at the POE10# pin

17.2.8 Input Level Control/Status Register 5 (ICSR5)

Address: 0008 C4D8h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	POE11F	—	—	POE11E	PIE5	—	—	—	—	—	—	POE11M[1:0]	
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	
b1, b0	POE11M[1:0]	POE11 Mode Select	b1 b0 00: Accepts a request on the falling edge of POE11# input 01: Accepts a request when POE11# input has been sampled 16 times at PCLK/8 clock pulses and all are low level. 10: Accepts a request when POE11# input has been sampled 16 times at PCLK/16 clock pulses and all are low level. 11: Accepts a request when POE11# input has been sampled 16 times at PCLK/128 clock pulses and all are low level.	R/W*1
b7 to b2	—	Reserved	These bits are always read as 0. The write value should be 0.	RW
b8	PIE5	Port Interrupt Enable 5	0: Interrupt requests disabled. 1: Interrupt requests enabled.	R/W
b9	POE11E	POE11 High-Impedance Enable	0: Does not place the pin in high-impedance state. 1: Places the pin in high-impedance state.	R/W*1
b11, b10	—	Reserved	These bits are always read as 0. The write value should be 0.	RW
b12	POE11F	POE11 Flag	0: Indicates that a high-impedance request has not been input to the POE11# pin. 1: Indicates that a high-impedance request has been input to the POE11# pin.	R/(W)*2
b15 to b13	—	Reserved	These bits are always read as 0. The write value should be 0.	RW

Note 1. Can be modified only once after a reset.
Note 2. Writing 0 to this bit after reading it as 1 clears the flag and is the only allowed way.

ICSR5 selects the POE11# pin input mode, controls the enable/disable of interrupts, and indicates status.

POE11M[1:0] Bits (POE11 Mode Select)

These bits select the input mode of the POE11# pin.

PIE5 Bit (Port Interrupt Enable 5)

This bit enables or disables interrupt requests when the POE11F bit is set to 1.

POE11E Bit (POE11 High-Impedance Enable)

This bit specifies whether to place the corresponding pin in high-impedance state when the POE11F bit is set to 1.

POE11F Flag (POE11 Flag)

This flag indicates that a request for the high-impedance state has been input to the POE11# pin.
[Clearing condition]

- By writing 0 to POE11F after reading POE11F = 1

[Setting condition]

- When the input set by POE11M[1:0] occurs at the POE11# pin

17.2.9 Software Port Output Enable Register (SPOER)

Address: 0008 C4CAh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	GPT23 HIZ	GPT01 HIZ	MTUC H0HIZ	MTUC H67HIZ	MTUC H34HIZ
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	MTUCH34HIZ	MTU3 and MTU4 Output High-Impedance Enable	0: Does not place the pins in high-impedance state. 1: Places the pins in high-impedance state.	R/W
b1	MTUCH67HIZ	MTU6 and MTU7 Output High-Impedance Enable	0: Does not place the pins in high-impedance state. 1: Places the pins in high-impedance state.	R/W
b2	MTUCH0HIZ	MTU0 Output High-Impedance Enable	0: Does not place the pins in high-impedance state. 1: Places the pins in high-impedance state.	R/W
b3	GPT01HIZ	GPT0 and GPT1 Output High-Impedance Enable	0: Does not place the pins in high-impedance state. 1: Places the pins in high-impedance state.	R/W
b4	GPT23HIZ	GPT2 and GPT3 Output High-Impedance Enable	These bits are always read as 0. The write value should be 0.	RW
b7 to b5	—	Reserved	These bits are always read as 0. The write value should be 0.	RW

SPOER controls high-impedance state of the pins.

MTUCH34HIZ Bit (MTU3 and MTU4 Output High-Impedance Enable)

This bit specifies whether to place the MTU complementary PWM output pins (MTIOC3B, MTIOC3D, MTIOC4A, MTIOC4B, MTIOC4C, MTIOC4D) or the GPT large-current output pins (GTIOC0A-A, GTIOC0B-A, GTIOC1A-A, GTIOC1B-A, GTIOC2A-A, GTIOC2B-A) in high-impedance state.

[Clearing conditions]

- Reset

By writing 0 to MTUCH34HIZ after reading MTUCH34HIZ = 1

[Setting condition]

- By writing 1 to MTUCH34HIZ

MTUCH67HIZ Bit (MTU6 and MTU7 Output High-Impedance Enable)

This bit specifies whether to place the MTU complementary PWM output pins (MTIOC6B, MTIOC6D, MTIOC7A, MTIOC7B, MTIOC7C, MTIOC7D) in the high-impedance state.

[Clearing conditions]

- Reset
- By writing 0 to MTUCH67HIZ after reading MTUCH67HIZ = 1

[Setting condition]

- By writing 1 to MTUCH67HIZ

MTUCH0HIZ Bit (MTU0 Output High-Impedance Enable)

This bit specifies whether to place the MTU0 pins in high-impedance state.
[Clearing conditions]

- Reset
- By writing 0 to MTUCH0HIZ after reading MTUCH0HIZ = 1

[Setting condition]

- By writing 1 to MTUCH0HIZ

GPT01HIZ Bit (GPT0 and GPT1 Output High-Impedance Enable)

This bit specifies whether to place the GPT0 and GPT1 pins (GTIOC0A-B, GTIOC0B-B, GTIOC1A-B, GTIOC1B-B) in high-impedance state.
[Clearing conditions]

- Reset
- By writing 0 to GPT01HIZ after reading GPT01HIZ = 1

[Setting condition]

- By writing 1 to GPT01HIZ

GPT23HIZ Bit (GPT2 and GPT3 Output High-Impedance Enable)

This bit specifies whether to place the GPT2 and GPT3 pins (GTIOC2A-B, GTIOC2B-B, GTIOC3A-B, GTIOC3B-B) in high-impedance state.
[Clearing conditions]

- Reset
- By writing 0 to GPT23HIZ after reading GPT23HIZ = 1

[Setting condition]

- By writing 1 to GPT23HIZ

17.2.10 Port Output Enable Control Register 1 (POECR1)

Address: 0008 C4CBh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	MTU0DZE	MTU0CZE	MTU0BZE	MTU0AZE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	MTU0AZE	MTU CH0A High-Impedance Enable	0: Does not place the pin in high-impedance state. 1: Places the pin in high-impedance state.	R/W*1
b1	MTU0BZE	MTU CH0B High-Impedance Enable	0: Does not place the pin in high-impedance state. 1: Places the pin in high-impedance state.	R/W*1
b2	MTU0CZE	MTU CH0C High-Impedance Enable	0: Does not place the pin in high-impedance state. 1: Places the pin in high-impedance state.	R/W*1
b3	MTU0DZE	MTU CH0D High-Impedance Enable	0: Does not place the pin in high-impedance state. 1: Places the pin in high-impedance state.	R/W*1
b7 to b4	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W

Note 1. Can be modified only once after a reset.

POECR1 controls high-impedance state of the MTU0 pins.

MTU0AZE Bit (MTU CH0A High-Impedance Enable)

This bit specifies whether to place the MTIOC0A-A and MTIOC0A-B outputs for the MTU0 in high-impedance state when any of the POE8F flag in ICSR3, MTUCH0HIZ bit in SPOER, OSTST bit in NMISR of the ICU, or, as additionally specified in the POECR5, the POEmF (n is 1, 2, 4, or 5, m is 0, 4, 10, or 11) flag in ICSRn and CjFLAG (j is 0 to 2, 4 to 6) flag in ADCMPFR of the S12ADA, is set to 1.

MTU0BZE Bit (MTU CH0B High-Impedance Enable)

This bit specifies whether to place the MTIOC0B-A and MTIOC0B-B outputs for the MTU0 in high-impedance state when any of the POE8F flag in ICSR3, MTUCH0HIZ bit in SPOER, OSTST bit in NMISR of the ICU, or, as additionally specified in the POECR5, the POEmF (n is 1, 2, 4, or 5, m is 9, 4, 10, or 11)flag in ICSRn and CjFLAG(j is 0 to 2, 4 to 6) flag in ADCMPFR of the S12ADA, is set to 1.

MTU0CZE Bit (MTU CH0C High-Impedance Enable)

This bit specifies whether to place the MTIOC0C pin for the MTU0 pin in high-impedance state when any of the POE8F flag in ICSR3, MTUCH0HIZ bit in SPOER, and OSTST bit in NMISR of the ICU, or, as additionally specified in the POECR5, the POEmF (n is 1, 2, 4, or 5, m is 0, 4, 10, or 11) flag in ICSRn and CjFLAG (j is 0 to 2, or 4 to 6) flag in ADCMPFR of the S12ADA, is set to 1.

MTU0DZE Bit (MTU CH0D High-Impedance Enable)

This bit specifies whether to place the MTIOC0D pin for the MTU0 pin in high-impedance state when any of the POE8F flag in ICSR3, CH0HIZ bit in SPOER, and OSTST bit in NMISR of the ICU, or, as additionally specified in the POECR5, the POEmF(n is 1, 2, 4, or 5, m is 0, 4, 10, or 11) flag in ICSRn and CjFLAG (j is 0 to 2, 4 to 6) flag in ADCMPFR of the S12ADA, is set to 1.

17.2.11 Port Output Enable Control Register 2 (POECR2)

Address: 0008 C4CCh

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	MTU3BDZE	MTU4ACZE	MTU4BDZE	—	—	—	—	—	MTU6BDZE	MTU7ACZE	MTU7BDZE
Value after reset:	0	0	0	0	0	1	1	1	0	0	0	0	0	1	1	1

Bit	Symbol	Bit Name	Description	R/W
b0	MTU7BDZE	MTU CH7BD High-Impedance Enable	0: Does not place the pins in high-impedance state. 1: Places the pins in high-impedance state.	R/W*1
b1	MTU7ACZE	MTU CH7AC High-Impedance Enable	0: Does not place the pins in high-impedance state. 1: Places the pins in high-impedance state.	R/W*1
b2	MTU6BDZE	MTU CH6BD High-Impedance Enable	0: Does not place the pins in high-impedance state. 1: Places the pins in high-impedance state.	R/W*1
b7 to b3	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W
b8	MTU4BDZE	MTU CH4BD High-Impedance Enable	0: Does not place the pins in high-impedance state. 1: Places the pins in high-impedance state.	R/W*1
b9	MTU4ACZE	MTU CH4AC High-Impedance Enable	This bit is always read as 0. The write value should be 0.	RW*1
b10	MTU3BDZE	MTU CH3BD High-Impedance Enable	0: Does not place the pins in high-impedance state. 1: Places the pins in high-impedance state.	R/W*1
b15 to b11	—	Reserved	These bits are always read as 0. The write value should be 0.	RW

Note 1. Can be modified only once after a reset.

POECR2 controls high-impedance state of the MTU complementary PWM output pins (MTU3, MTU4, MTU6, and MTU7 pins) and the GPT large-current output pin (GPT0 to GPT2 pins).

MTU7BDZE Bit (MTU CH7BD High-Impedance Enable)

This bit specifies whether to place the MTIOC7B and MTIOC7D pins for the MTU7 pin when any one of the OSF2 flag in OCSR2, POE4F flag in ICSR2, and MTUCH67HIZ bit in SPOER, OSTST bit in NMISR of the ICU or, as additionally specified in the POECR4 register, the POEmF (n is 1, 3 to 5, m is 0, 8, 10, or 11) flag in ICSRn and CjFLAG (j is 0 to 2, 4 to 6) flag in ADCMPFR of the S12ADA, is set to 1.

MTU7ACZE Bit (MTU CH7AC High-Impedance Enable)

This bit specifies whether to place the MTIOC7A and MTIOC7C pins for the MTU7 pin in high-impedance state when any one of the OSF2 flag in OCSR2, POE4F flag in ICSR2, and MTUCH67HIZ bit in SPOER, OSTST bit in NMISR of the ICU or, as additionally specified in the POECR4 register, the POEmF (n is 1, 3 to 5, m is 0, 8, 10, or 11)flag in ICSRn and CjFLAG(j is 0 to 2, 4 to 6) flag in ADCMPFR of the S12ADA, is set to 1.

MTU6BDZE Bit (MTU CH6BD High-Impedance Enable)

This bit specifies whether to place the MTIOC6B and MTIOC6D pins for the MTU6 pin in high-impedance state when any one of the OSF2 flag in OCSR2, POE4F flag in ICSR2, and MTUCH67HIZ bit in SPOER, OSTST bit in NMISR of the ICU or, as additionally specified in the POECR4 register, the POEmF (n is 1, 3 to 5, m is 0, 8, 10, or 11) flag in ICSRn and CjFLAG(j is 0 to 2, 4 to 6) flag in ADCMPFR of the S12ADA, is set to 1.

MTU4BDZE Bit (MTU CH4BD High-Impedance Enable)

This bit specifies whether to place the MTIOC4B /GTIOC2A-A output and MTIOC4D/GTIOC2B-A outputs for the MTU4/GPT2 pin in high-impedance state when any one of the OSF1 flag in OCSR1, POE0F flag in ICSR1, MTUCH34HIZ bit in SPOER, OSTST bit in NMISR of the ICU or, as additionally specified in the POECR4 register, the POEmF(n is 2 to 5, m is 4, 8, 10, or 11)flag in ICSRn and CjFLAG (j is 0 to 2, 4 to 6) flag in ADCMPFR of the S12ADA, is set to 1.

MTU4ACZE Bit (MTU CH4AC High-Impedance Enable)

This bit specifies whether to place the MTIOC4A/GTIOC1A-A output and MTIOC4C/GTIOC1B-A outputs for the MTU4/GPT1 pin in high-impedance state when any one of the OSF1 flag in OCSR1, POE0F flag in ICSR1, MTUCH34HIZ bit in SPOER, OSTST bit in NMISR of the ICU or, as additionally specified in the POECR4 register, the POEmF (n is 2 to 5, m is 4, 8, 10, or 11) flag in ICSRn and CjFLAG (j is 0 to 2, 4 to 6) flag in ADCMPFR of the S12ADA, is set to 1.

MTU3BDZE Bit (MTU CH3BD High-Impedance Enable)

This bit specifies whether to place the MTIOC3B/GTIOC0A-A output and MTIOC3D/GTIOC0B-A outputs for the MTU3/GPT0 pin in high-impedance state when any one of the OSF1 flag in OCSR1, POE0F flag in ICSR1, MTUCH34HIZ bit in SPOER, OSTST bit in NMISR of the ICU or, as additionally specified in the POECR4 register, the POEmF (n is 2 to 5, m is 4, 8, 10, or 11) flag in ICSRn and CjFLAG (j is 0 to 2, 4 to 6) flag in ADCMPFR of the S12ADA, is set to 1.

17.2.12 Port Output Enable Control Register 3 (POECR3)

Address: 0008 C4CEh

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	GPT3ABZE	GPT2ABZE	—	—	—	—	—	—	GPT1ABZE	GPT0ABZE
Value after reset:	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1

Bit	Symbol	Bit Name	Description	R/W
b0	GPT0ABZE	GPT CH0AB High-Impedance Enable	0: Does not place the pins in high-impedance state. 1: Places the pins in high-impedance state.	R/W*1
b1	GPT1ABZE	GPT CH1AB High-Impedance Enable	0: Does not place the pins in high-impedance state. 1: Places the pins in high-impedance state.	R/W*1
b7 to b2	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W
b8	GPT2ABZE	GPT CH2AB High-Impedance Enable	0: Does not place the pins in high-impedance state. 1: Places the pins in high-impedance state.	R/W*1
b9	GPT3ABZE	GPT CH3AB High-Impedance Enable	0: Does not place the pins in high-impedance state. 1: Places the pins in high-impedance state.	R/W*1
b10 to b15	—	Reserved	These bits are always read as 0. The write value should be 0	RW

Note 1. Can be modified only once after a reset.

POECR3 controls high-impedance state of the GPT pin.

GPT0ABZE Bit (GPT CH0AB High-Impedance Enable)

This bit specifies whether to place the GTIOC0A-B and GTIOC0B-B outputs for the GPT0 pin when any one of the POE10F flag in ICSR4, GPT01HIZ bit in SPOER, OSTST bit in NMISR of the ICU or, as additionally specified in the POECR6, the POEmF (n is 1 to 5, m is 0, 4, 8, or 11) flag in ICSRn and CjFLAG (j is 0 to 2, 4 to 6) flag in ADCMPFR of the S12ADA, is set to 1.

GPT1ABZE Bit (GPT CH1AB High-Impedance Enable)

This bit specifies whether to place the GTIOC1A-B and GTIOC1B-B outputs for the GPT1 pin when any one of the POE10F flag in ICSR4, GPT01HIZ bit in SPOER, OSTST bit in NMISR of the ICU, as additionally specified in the POECR6, the POEmF (n is 1 to 4, m is 0, 4, 8, or 10) flag in ICSRn and CjFLAG (j is 0 to 2, 4 to 6) flag in ADCMPFR of the S12ADA, is set to 1.

GPT2ABZE Bit (GPT CH2AB High-Impedance Enable)

This bit specifies whether to place the GTIOC2A-B and GTIOC2B-B outputs for the GPT2 pin when any one of the POE11F flag in ICSR5, GPT23HIZ bit in SPOER, OSTST bit in NMISR of the ICU, as additionally specified in the POECR6, the POEmF (n is 0 to 2, m is 4 to 6)flag in ICSRn and CjFLAG (j is 0 to 2, 4 to 6) flag in ADCMPFR of the S12ADA, is set to 1.

GPT3ABZE Bit (GPT CH3AB High-Impedance Enable)

This bit specifies whether to place the GTIOC3A and GTIOC3B outputs for the GPT3 pin when any one of the POE11F flag in ICSR5, GPT23HIZ bit in SPOER, OSTST bit in NMISR of the ICU, as additionally specified in the POECR6, the POEmF (n is 1 to 4, m is 0, 4, 8, or 10)flag in ICSRn and CjFLAG (j is 0 to 2, 4 to 6) flag in ADCMPFR of the S12ADA, is set to 1.

17.2.13 Port Output Enable Control Register 4 (POECR4)

Address: 0008 C4D0h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	IC5AD DMT67	IC4AD DMT67	IC3AD DMT67	—	IC1AD DMT67	CMAD DMT67	—	—	IC5AD DMT34	IC4AD DMT34	IC3AD DMT34	IC2AD DMT34	—	CMAD DMT34
Value after reset:	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0

Bit	Symbol	Bit Name	Description	R/W
b0	CMADDMT34ZE	MTU CH34 High-Impedance CFLAG Add	0: Does not add the pins to the high-impedance control conditions. 1: Adds the pins to high-impedance control conditions.	R/W*1
b1	—	Reserved	This bit is always read as 1. The write value should be 1.	RW
b2	IC2ADDMT34ZE	MTU CH34 High-Impedance POE4F Add	0: Does not add the pins to high-impedance control conditions. 1: Adds the pins to high-impedance control conditions.	R/W*1
b3	IC3ADDMT34ZE	MTU CH34 High-Impedance POE8F Add	0: Does not add the pins to high-impedance control conditions. 1: Adds the pins to high-impedance control conditions.	
b4	IC4ADDMT34ZE	MTU CH34 High-Impedance POE10F Add	0: Does not add the pins to the high-impedance control conditions. 1: Adds the pins to high-impedance control conditions.	R/W*1
b5	IC5ADDMT34ZE	MTU CH34 High-Impedance POE11F Add	0: Does not add the pins the high-impedance control conditions. 1: Adds the pins to high-impedance conditions.	R/W*1
b6, b7	—	Reserved	These bits are always read as 0. The write value should be 0	R/W
b8	CMADDMT67ZE	MTU CH67 High-Impedance CFLAG Add	0: Does not add the pins to the high-impedance control conditions. 1: Adds the pins to high-impedance control conditions.	R/W*1
b9	IC1ADDMT67ZE	MTU CH67 High-Impedance POE0F Add	0: Does not add the pins to the high-impedance control conditions. 1: Adds the pins to high-impedance control conditions.	R/W*1
b10	—	Reserved	This bit is always read as 1. The write value should be 1.	R/W
b11	IC3ADDMT67ZE	MTU CH67 High-Impedance POE8F Add	0: Does not add the pins to the high-impedance control conditions. 1: Adds the pins to high-impedance control conditions.	R/W*1
b12	IC4ADDMT67ZE	MTU CH67 High-Impedance POE10F Add	0: Does not add the pins to the high-impedance control conditions. 1: Adds the pins to high-impedance control conditions.	R/W*1
b13	IC5ADDMT67ZE	MTU CH67 High-Impedance POE11F Add	0: Does not add the pins to the high-impedance control conditions. 1: Adds the pins to high-impedance control conditions.	R/W*1
b14, b15	—	Reserved	These bits are always read as 0. The write value should be 0	R/W

Note 1. Can be modified only once after a reset.

The POECR4 is used to extend the control conditions of the high-impedance state for the MTU3, MTU4, MTU6, and MTU7 pins for the MTU complementary PWM output and the GPT0 to GPT2 pins for the GPT large-current output.

CMADDMT34ZE Bit (MTU CH34 High-Impedance CFLAG Add)

Adds the CjFLAG (j is 0 to 2, and 4 to 6) flag in the ADCMPFR of the S12ADA to the high-impedance control conditions for the MTU3, MTU4, and GPT0 to GPT2 pins (MTIOC3B/MTIOC3D/GTIOC0A-A/GTIOC0B-A/MTIOC4A/MTIOC4C/GTIOC1A-A/GTIOC1B-A/MTIOC4B/MTIOC4D/GTIOC2A-A/GTIOC2B-A). However, when this flag is placed in the high-impedance, the OEIn (n is 1 to 4) interrupt will not occur.

IC2ADDMT34ZE Bit (MTU CH34 High-Impedance POE4F Add)

Adds the POE4F flag in ICSR2 to the high-impedance control conditions for the MTU3, MTU4, and GPT0 to GPT2 pins (MTIOC3B/MTIOC3D/GTIOC0A-A/GTIOC0B-A/MTIOC4A/MTIOC4C/GTIOC1A-A/GTIOC1B-A/MTIOC4B/MTIOC4D/GTIOC2A-A/GTIOC2B-A).

IC3ADDMT34ZE Bit (MTU CH34 High-Impedance POE8F Add)

Adds the POE8F flag in ICSR3 to the high-impedance control conditions for the MTU3, MTU4, and GPT0 to GPT2 pins (MTIOC3B/MTIOC3D/GTIOC0A-A/GTIOC0B-A/MTIOC4A/MTIOC4C/GTIOC1A-A/GTIOC1B-A/MTIOC4B/MTIOC4D/GTIOC2A-A/GTIOC2B-A).

IC4ADDMT34ZE Bit (MTU CH34 High-Impedance POE10F Add)

Adds the POE10F flag in ICSR4 to the high-impedance control conditions for the MTU3, MTU4, and GPT0 to GPT2 pins (MTIOC3B/MTIOC3D/GTIOC0A-A/GTIOC0B-A/MTIOC4A/MTIOC4C/GTIOC1A-A/GTIOC1B-A/MTIOC4B/MTIOC4D/GTIOC2A-A/GTIOC2B-A).

IC5ADDMT34ZE Bit (MTU CH34 High-Impedance POE11F Add)

Adds the POE11F flag in ICSR5 to the high-impedance control conditions for the MTU3, MTU4, and GPT0 to GPT2 pins (MTIOC3B/MTIOC3D/GTIOC0A-A/GTIOC0B-A/MTIOC4A/MTIOC4C/GTIOC1A-A/GTIOC1B-A/MTIOC4B/MTIOC4D/GTIOC2A-A/GTIOC2B-A).

CMADDMT67ZE Bit (MTU CH67 High-Impedance CFLAG Add)

The CjFLAG (j is 0 to 2, and 4 to 6) flag in the ADCMPFR of the S12ADA is added to the high-impedance control conditions for the MTU6, and MTU7 pins (MTIOC6B/MTIOC6D/MTIOC7A/MTIOC7C/MTIOC7B/MTIOC7D). However, when those flags are placed in the high-impedance, the OEIn (n is 1 to 4) interrupt will not occur.

IC1ADDMT67ZE Bit (MTU CH67 High-Impedance POE0F Add)

Adds the POE0F flag in ICSR1 to the high-impedance control conditions for the MTU6 and MTU7 pins (MTIOC6B/MTIOC6D/MTIOC7A/MTIOC7C/MTIOC7B/MTIOC7D).

IC3ADDMT67ZE Bit (MTU CH67 High-Impedance POE8F Add)

Adds the POE8F flag in ICSR3 to the high-impedance control conditions for the MTU6 and MTU7 pins (MTIOC6B/MTIOC6D/MTIOC7A/MTIOC7C/MTIOC7B/MTIOC7D).

IC4ADDMT67ZE Bit (MTU CH67 High-Impedance POE10F Add)

Adds the POE10F flag in ICSR4 to the high-impedance control conditions for the MTU6 and MTU7 pins (MTIOC6B/MTIOC6D/MTIOC7A/MTIOC7C/MTIOC7B/MTIOC7D).

IC5ADDMT67ZE Bit (MTU CH67 High-Impedance POE11F Add)

Adds the POE11F flag in ICSR5 to the high-impedance control conditions for the MTU6 and MTU7 pins (MTIOC6B/MTIOC6D/MTIOC7A/MTIOC7C/MTIOC7B/MTIOC7D).

17.2.14 Port Output Enable Control Register 5 (POECR5)

Address: 0008 C4D2h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	—	—	IC5ADDMT0Z	IC4ADDMT0Z	—	IC2ADDMT0Z	IC1ADDMT0Z	CMADDMT0Z
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	CMADDMT0Z	MTU CH0 High-Impedance CFLAG Add	0: Does not add the pins to the high-impedance control conditions. 1: Adds the pins to high-impedance control conditions.	R/W*1
b1	IC1ADDMT0Z	MTU CH0 High-Impedance POE0F Add	0: Does not add the pins to the high-impedance control conditions. 1: Adds the pins to high-impedance control conditions.	R/W*1
b2	IC2ADDMT0Z	MTU CH0 High-Impedance POE4F Add	0: Does not add the pins to the high-impedance control conditions. 1: Adds the pins to high-impedance control conditions.	R/W*1
b3	—	Reserved	This bit is always read as 1. The write value should be 1.	R/W
b4	IC4ADDMT0Z	MTU CH0 High-Impedance POE10F Add	0: Does not add the pins to the high-impedance control conditions. 1: Adds the pins to high-impedance control conditions.	R/W*1
b5	IC5ADDMT0ZE	MTU CH0 High-Impedance POE11F Add	0: Does not add the pins to the high-impedance control conditions. 1: Adds the pins to high-impedance control conditions.	R/W*1
b6 to b15	—	Reserved	These bits are always read as 0. The write value should be 0	R/W

Note 1. Can be modified only once after a reset.

The POECR5 is used to extend the control conditions of the high-impedance for the MTU0 pin.

CMADDMT0ZE Bit (MTU CH0 High-Impedance CFLAG Add)

The CjFLAG (j is 0 to 2, and 4 to 6) flag in the ADCMPFR of the S12ADA is added to the high-impedance control conditions for the MTU0 pins (MTIOC0A, MTIOC0B, MTIOC0C, MTIOC0D). However, when this flag is placed in the high-impedance, the OEIn (n is 1 to 4) interrupt will not occur.

IC1ADDMT0ZE Bit (MTU CH0 High-Impedance POE0F Add)

Adds the POE0F flag in ICSR1 to the high-impedance control conditions for the MTU0 pins (MTIOC0A, MTIOC0B, MTIOC0C, MTIOC0D).

IC2ADDMT0ZE Bit (MTU CH0 High-Impedance POE4F Add)

Adds the POE4F flag in ICSR2 to the high-impedance control conditions for the MTU0 pins (MTIOC0A, MTIOC0B, MTIOC0C, MTIOC0D).

IC4ADDMT0ZE Bit (MTU CH0 High-Impedance POE10F Add)

Adds the POE10F flag in ICSR4 to the high-impedance control conditions for the MTU0 pins (MTIOC0A, MTIOC0B, MTIOC0C, MTIOC0D).

IC5ADDMT0ZE Bit (MTU CH0 High-Impedance POE11F Add)

Adds the POE11F flag in ICSR5 to the high-impedance control conditions for the MTU0 pins (MTIOC0A, MTIOC0B, MTIOC0C, MTIOC0D).

17.2.15 Port Output Enable Control Register 6 (POECR6)

Address: 0008 C4D4h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	IC4AD DGPT2	IC3AD DGPT2	IC2AD DGPT2	IC1AD DGPT2	CMAD DGPT2	—	—	IC5AD DGPT0	—	IC3AD DGPT0	IC2AD DGPT0	IC1AD DGPT0	CMAD DGPT0
Value after reset:	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	CMADDGPT0	GPT CH01 High-Impedance CFLAG Add	0: Does not add the pins to the high-impedance control conditions. 1: Adds the pins to high-impedance control conditions.	R/W*1
b1	IC1ADDGPT0	GPT CH01 High-Impedance POE0F Add	0: Does not add the pins to the high-impedance control conditions. 1: Adds the pins to high-impedance control conditions.	R/W*1
b2	IC2ADDGPT0	GPT CH01 High-Impedance POE4F Add	0: Does not add the pins to the high-impedance control conditions. 1: Adds the pins to high-impedance control conditions.	R/W*1
b3	IC3ADDGPT0	GPT CH01 High-Impedance POE8F Add	0: Does not add the pins to the high-impedance control conditions. 1: Adds the pins to high-impedance control conditions.	R/W*1
b4	—	Reserved	This bit is always read as 1. The write value should be 1.	R/W
b5	IC5ADDGPT0	GPT CH01 High-Impedance POE11F Add	0: Does not add the pins to the high-impedance control conditions. 1: Adds the pins to high-impedance control conditions.	R/W*1
b7, b6	—	Reserved	These bits are always read as 0. The write value should be 0	R/W
b8	CMADDGPT23ZE	GPT CH23 High-Impedance CFLAG Add	0: Does not add the pins to the high-impedance control conditions. 1: Adds the pins to high-impedance control conditions.	R/W*1
b9	IC1ADDGPT23ZE	GPT CH23 High-Impedance POE0F Add	0: Does not add the pins to the high-impedance control conditions. 1: Adds the pins to high-impedance control conditions.	R/W*1
b10	IC2ADDGPT23ZE	GPT CH23 High-Impedance POE4F Add	0: Does not add the pins to the high-impedance control conditions. 1: Adds the pins to high-impedance control conditions.	R/W*1
b11	IC3ADDGPT23ZE	GPT CH23 High-Impedance POE8F Add	0: Does not add the pins to the high-impedance control conditions. 1: Adds the pins to high-impedance control conditions.	R/W*1
b12	IC4ADDGPT23ZE	GPT CH23 High-Impedance POE10F Add	0: Does not add the pins to the high-impedance control conditions. 1: Adds the pins to high-impedance control conditions.	R/W*1
b13	—	Reserved	This bit is always read as 1. The write value should be 1.	R/W
b14, b15	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W

Note 1. Can be modified only once after a reset.

The POECR6 is used to extend the control conditions of the high-impedance for the GPT0 to GPT3 pins.

CMADDGPT01ZE Bit (GPT CH01 High-Impedance CFLAG Add)

Adds the CjFLAG (j is 0 to 2, and 4 to 6) flag in the ADCMPFR of the S12ADA to the high-impedance control conditions for the GPT0 and GPT1 pins (GTIOC0A-B, GTIOC0B-B, GTIOC1A-B, GTIOC1B-B). However, when this flag is placed in the high-impedance, the OEIn (n is 1 to 4) interrupt will not occur.

IC1ADDGPT01ZE Bit (GPT CH01 High-Impedance POE0F Add)

Adds the POE0F flag in ICSR1 to the high-impedance control conditions for the GPT0 and GPT1 pins (GTIOC0A-B, GTIOC0B-B, GTIOC1A-B, GTIOC1B-B).

IC2ADDGPT01ZE Bit (GPT CH01 High-Impedance POE4F Add)

Adds the POE4F flag in ICSR2 to the high-impedance control conditions for the GPT0 and GPT1 pins (GTIOC0A-B, GTIOC0B-B, GTIOC1A-B, GTIOC1B-B).

IC3ADDGPT01ZE Bit (GPT CH01 High-Impedance POE8F Add)

Adds the POE8F flag in ICSR3 to the high-impedance control conditions for the GPT0 and GPT1 pins (GTIOC0A-B, GTIOC0B-B, GTIOC1A-B, GTIOC1B-B).

IC5ADDGPT01ZE Bit (GPT CH01 High-Impedance POE11F Add)

Adds the POE11F flag in ICSR5 to the high-impedance control conditions for the GPT0 and GPT1 pins (GTIOC0A-B, GTIOC0B-B, GTIOC1A-B, GTIOC1B-B).

CMADDGPT23ZE Bit (GPT CH23 High-Impedance CFLAG Add)

The CjFLAG (j is 0 to 2, and 4 to 6) flag in the ADCMPFR of the S12ADA is added to the high-impedance control conditions for the GPT2 and GPT3 pins (GTIOC2A-B, GTIOC2B-B, GTIOC3A-B, GTIOC3B-B). However, when those flags are placed in the high-impedance, the OEIn (n is 1 to 4) interrupt will not occur.

IC1ADDGPT23ZE Bit (GPT CH23 High -Impedance POE0F Add)

Adds the POE0F flag in ICSR1 to the high-impedance control conditions for the GPT2 and GPT3 pins (GTIOC2A-B, GTIOC2B-B, GTIOC3A-B, GTIOC3B-B).

IC2ADDGPT23ZE Bit (GPT CH23 High -Impedance POE4F Add)

Adds the POE4F flag in ICSR2 to the high-impedance control conditions for the GPT2 and GPT3 pins (GTIOC2A-B, GTIOC2B-B, GTIOC3A-B, GTIOC3B-B).

IC3ADDGPT23ZE Bit (GPT CH23 High -Impedance POE8F Add)

Adds the POE8F flag in ICSR3 to the high-impedance control conditions for the GPT2 and GPT3 pins (GTIOC2A-B, GTIOC2B-B, GTIOC3A-B, GTIOC3B-B).

IC4ADDGPT23ZE Bit (GPT CH23 High -Impedance POE10F Add)

Adds the POE10F flag in ICSR4 to the high-impedance control conditions for the GPT2 and GPT3 pins (GTIOC2A-B, GTIOC2B-B, GTIOC3A-B, GTIOC3B-B).

17.3 Operation

Table 17.5 shows the target pins for high-impedance control and conditions to place the pins in high-impedance state.

Table 17.5 Target Pins and Conditions for High-Impedance Control (1 / 4)

Pins	Conditions	Detailed Conditions
MTU3B/MTU3D pins (MTIOC3B and MTIOC3D)	• POE0# input level detection • MTIOC3B and MTIOC3D output level comparison • SPOER setting • Detection of stopped oscillation • Additional conditions of the POECR4 – 12-bit A/D converter comparator detection – POE4#, POE8#, POE10#, POE11# input level detection	MTU3BDZE· ((POE0F) + (OSF1•OCE1) + (MTUCH34HIZ) + (ICU.NMISR.OSTST) + (CMADDMT34ZE· S12AD.ADCMPSEL.POE· (S12AD.ADCMPFR.CnFLAG)) + (IC2ADDMT34ZE•POE4F) + (IC3ADDMT34ZE•POE8E•POE8F) + (IC4ADDMT34ZE•POE10E•POE10F) + (IC5ADDMT34ZE•POE11E•POE11F)) (n = 0 to 2, 4 to 6)
MTU4A/MTU4C pins (MTIOC4A and MTIOC4C)	• POE0# input level detection • MTIOC4A and MTIOC4C output level comparison • SPOER setting • Detection of stopped oscillation • Additional conditions of the POECR4 – 12-bit A/D converter comparator detection – POE4#, POE8#, POE10#, POE11# input level detection	MTU4ACZE· ((POE0F) + (OSF1•OCE1) + (MTUCH34HIZ) + (ICU.NMISR.OSTST) + (CMADDMT34ZE· S12AD.ADCMPSEL.POE· (S12AD.ADCMPFR.CnFLAG)) + (IC2ADDMT34ZE•POE4F) + (IC3ADDMT34ZE•POE8E•POE8F) + (IC4ADDMT34ZE•POE10E•POE10F) + (IC5ADDMT34ZE•POE11E•POE11F)) (n = 0 to 2, 4 to 6)
MTU4B/MTU4D pins (MTIOC4B and MTIOC4D)	• POE0# input level detection • MTIOC4B and MTIOC4D output level comparison • SPOER setting • Detection of stopped oscillation • Additional conditions of the POECR4 – 12-bit A/D converter comparator detection – POE4#, POE8#, POE10#, POE11# input level detection	MTU4BDZE· ((POE0F) + (OSF1•OCE1) + (MTUCH34HIZ) + (ICU.NMISR.OSTST) + (CMADDMT34ZE· S12AD.ADCMPSEL.POE· (S12AD.ADCMPFR.CnFLAG)) + (IC2ADDMT34ZE•POE4F) + (IC3ADDMT34ZE•POE8E•POE8F) + (IC4ADDMT34ZE•POE10E•POE10F) + (IC5ADDMT34ZE•POE11E•POE11F)) (n = 0 to 2, 4 to 6)
MTU6B/MTU6D pins (MTIOC6B and MTIOC6D)	• POE4# input level detection • MTIOC6B and MTIOC6D output level comparison • SPOER setting • Detection of stopped oscillation • Additional conditions of the POECR4 – 12-bit A/D converter comparator detection – POE4#, POE8#, POE10#, POE11# input level detection	MTU6BDZE· (POE4F + (OSF2•OCE2) + (MTUCH67HIZ) + (ICU.NMISR.OSTST) + (CMADDMT67ZE· S12AD.ADCMPSEL.POE· (S12AD.ADCMPFR.CnFLAG)) + (IC1ADDMT67ZE•POE0F) + (IC3ADDMT67ZE•POE8E•POE8F) + (IC4ADDMT67ZE•POE10E•POE10F) + (IC5ADDMT67ZE•POE11E•POE11F)) (n = 0 to 2, 4 to 6)

Table 17.5 Target Pins and Conditions for High-Impedance Control (2 / 4)

Pins	Conditions	Detailed Conditions
MTU7A/MTU7C pins (MTIOC7A and MTIOC7C)	• POE4# input level detection • MTIOC7A and MTIOC7C output level comparison • SPOER setting • Detection of stopped oscillation • Additional conditions of the POECR4 – 12-bit A/D converter comparator detection – POE4#, POE8#, POE10#, POE11# input level detection	MTU7ACZE· ((POE4F) + (OSF2•OCE2) + (MTUCH67HIZ) + (ICU.NMISR.OSTST) + (CMADDMT67ZE· S12AD.ADCMPSEL.POE· (S12AD.ADCMPFR.CnFLAG)) + (IC1ADDMT67ZE•POE0F) + (IC3ADDMT67ZE•POE8E•POE8F) + (IC4ADDMT67ZE•POE10E•POE10F) + (IC5ADDMT67ZE•POE11E•POE11F)) (n = 0 to 2, 4 to 6)
MTU7B/MTU7D pins (MTIOC7B and MTIOC7D)	• POE4# input level detection • MTIOC7B and MTIOC7D output level comparison • SPOER setting • Detection of stopped oscillation • Additional conditions of the POECR4 – 12-bit A/D converter comparator detection – POE4#, POE8#, POE10#, POE11# input level detection	MTU7BDZE· ((POE4F + (OSF2•OCE2) + (MTUCH67HIZ) + (ICU.NMISR.OSTST) + (CMADDMT67ZE· S12AD.ADCMPSEL.POE· (S12AD.ADCMPFR.CnFLAG)) + (IC1ADDMT67ZE•POE0F) + (IC3ADDMT67ZE•POE8E•POE8F) + (IC4ADDMT67ZE•POE10E•POE10F) + (IC5ADDMT67ZE•POE11E•POE11F)) (n = 0 to 2, 4 to 6)
GPT0 pins (GTIOC0A-A and GTIOC0B-A)	• POE0# input level detection • GTIOC0A-A and GTIOC0B-A output level comparison • SPOER setting • Detection of stopped oscillation • Additional conditions of the POECR4 – 12-bit A/D converter comparator detection – POE4#, POE8#, POE10#, POE11# input level detection	MTU3BDZE· ((POE0F) + (OSF1•OCE1) + (MTUCH34HIZ) + (ICU.NMISR.OSTST) + (CMADDMT34ZE· S12AD.ADCMPSEL.POE· (S12AD.ADCMPFR.CnFLAG)) + (IC2ADDMT34ZE•POE4F) + (IC3ADDMT34ZE•POE8E•POE8F) + (IC4ADDMT34ZE•POE10E•POE10F) + (IC5ADDMT34ZE•POE11E•POE11F)) (n = 0 to 2, 4 to 6)
GPT1 pins (GTIOC1A-A and GTIOC1B-A)	• POE0# input level detection • GTIOC1A-A and GTIOC1B-A output level comparison • SPOER setting • Detection of stopped oscillation • Additional conditions of the POECR4 – 12-bit A/D converter comparator detection – POE4#, POE8#, POE10#, POE11# input level detection	MTU4ACZE· ((POE0F) + (OSF1•OCE1) + (MTUCH34HIZ) + (ICU.NMISR.OSTST) + (CMADDMT34ZE· S12AD.ADCMPSEL.POE· (S12AD.ADCMPFR.CnFLAG)) + (IC2ADDMT34ZE•POE4F) + (IC3ADDMT34ZE•POE8E•POE8F) + (IC4ADDMT34ZE•POE10E•POE10F) + (IC5ADDMT34ZE•POE11E•POE11F)) (n = 0 to 2, 4 to 6)

Table 17.5 Target Pins and Conditions for High-Impedance Control (3 / 4)

Pins	Conditions	Detailed Conditions
GPT2 pins (GTIOC2A-A and GTIOC2B-A)	• POE0# input level detection • GTIOC2A-A and GTIOC2B-A output level comparison • SPOER setting • Detection of stopped oscillation • Additional conditions of the POECR4 – 12-bit A/D converter comparator detection – POE4#, POE8#, POE10#, POE11# input level detection	MTU4BDZE· ((POE0F) + (OSF1•OCE1) + (MTUCH34HIZ) + (ICU.NMISR.OSTST) + (CMADDMT34ZE· S12AD.ADCMPSEL.POE· (S12AD.ADCMPFR.CnFLAG)) + (IC2ADDMT34ZE•POE4F) + (IC3ADDMT34ZE•POE8E•POE8F) + (IC4ADDMT34ZE•POE10E•POE10F) + (IC5ADDMT34ZE•POE11E•POE11F)) (n = 0 to 2, 4 to 6)
MTU0A pins (MTIOC0A-A and MTIOC0A-B)	• POE8# input level detection • SPOER setting • Detection of stopped oscillation • Additional conditions of the POECR5 – 12-bit A/D converter comparator detection – POE0#, POE4#, POE10#, POE11# input level detection	MTU0AZE· ((POE8F•POE8E) + (MTUCH0HIZ) + (ICU.NMISR.OSTST) + (CMADDMT0ZE· S12AD.ADCMPSEL.POE· + (S12AD.ADCMPFR.CnFLAG)) + (IC1ADDMT0ZE•POE0F) + (IC2ADDMT0ZE•POE4F) + (IC4ADDMT0ZE•POE10E•POE10F) + (IC5ADDMT0ZE•POE11E•POE11)) (n = 0 to 2, 4 to 6)
MTU0B pins (MTIOC0B-A and MTIOC0B-B)	• POE8# input level detection • SPOER setting • Detection of stopped oscillation • Additional conditions of the POECR5 – 12-bit A/D converter comparator detection – POE0#, POE4#, POE10#, POE11# input level detection	MTU0BZE· ((POE8F•POE8E) + (MTUCH0HIZ) + (ICU.NMISR.OSTST) + (CMADDMT0ZE· S12AD.ADCMPSEL.POE· (S12AD.ADCMPFR.CnFLAG)) + (IC1ADDMT0ZE•POE0F) + (IC2ADDMT0ZE•POE4F) + (IC4ADDMT0ZE•POE10E•POE10F) + (IC5ADDMT0ZE•POE11E•POE11F)) (n = 0 to 2, 4 to 6)
MTU0C pins (MTIOC0C)	• POE8# input level detection • SPOER setting • Detection of stopped oscillation • Additional conditions of the POECR5 – 12-bit A/D converter comparator detection – POE0#, POE4#, POE10#, POE11# input level detection	MTU0CZE· ((POE8F•POE8E) + (MTUCH0HIZ) + (ICU.NMISR.OSTST) + (CMADDMT0ZE· S12AD.ADCMPSEL.POE· (S12AD.ADCMPFR.CnFLAG)) + (IC1ADDMT0ZE•POE0F) + (IC2ADDMT0ZE•POE4F) + (IC4ADDMT0ZE•POE10E•POE10F) + (IC5ADDMT0ZE•POE11E•POE11F)) (n = 0 to 2, 4 to 6)
MTU0D pins (MTIOC0D)	• POE8# input level detection • SPOER setting • Detection of stopped oscillation • Additional conditions of the POECR5 – 12-bit A/D converter comparator detection – POE0#, POE4#, POE10#, POE11# input level detection	MTU0DZE· ((POE8F•POE8E) + (MTUCH0HIZ) + (ICU.NMISR.OSTST) + (CMADDMT0ZE· S12AD.ADCMPSEL.POE· (S12AD.ADCMPFR.CnFLAG)) + (IC1ADDMT0ZE•POE0F) + (IC2ADDMT0ZE•POE4F) + (IC4ADDMT0ZE•POE10E•POE10F)) + (IC5ADDMT0ZE•POE11E•POE11F)) (n = 0 to 2, 4 to 6)

Table 17.5 Target Pins and Conditions for High-Impedance Control (4 / 4)

Pins	Conditions	Detailed Conditions
GPT0 pins (GTIOC0A-B and GTIOC0B-B)	• POE10# input level detection • SPOER setting • Detection of stopped oscillation • Additional conditions of the POECR6 – 12-bit A/D converter comparator detection – POE0#, POE4#, POE8#, POE11# input level detection	GPT0ABZE? ((POE10F•POE10E) + (GPT01HIZ) + (ICU.NMISR.OSTST) + (CMADDGPT01ZE· S12AD.ADCMPSEL.POE· (S12AD.ADCMPFR.CnFLAG)) + (IC1ADDGPT01ZE•POE0F) + (IC2ADDGPT01ZE•POE4F) + (IC3ADDGPT01ZE•POE8E•POE8F) + (IC5ADDGPT01ZE•POE11E•POE11F)) (n = 0 to 2, 4 to 6)
GPT1pins (GTIOC1A-B and GTIOC1B-B)	• POE10# input level detection • SPOER setting • Detection of stopped oscillation • Additional conditions of the POECR6 – 12-bit A/D converter comparator detection – POE0#, POE4#, POE8#, POE11# input level detection	GPT1ABZE? ((POE10F•POE10E) + (GPT01HIZ) + (ICU.NMISR.OSTST) + (CMADDGPT01ZE· S12AD.ADCMPSEL.POE· (S12AD.ADCMPFR.CnFLAG)) + (IC1ADDGPT01ZE•POE0F) + (IC2ADDGPT01ZE•POE4F) + (IC3ADDGPT01ZE•POE8E•POE8F) + (IC5ADDGPT01ZE•POE11E•POE11F)) (n = 0 to 2, 4 to 6)
GPT2 pins (GTIOC2A-B and GTIOC2B-B)	• POE11# input level detection • SPOER setting • Detection of stopped oscillation • Additional conditions of the POECR6 – 12-bit A/D converter comparator detection – POE0#, POE4#, POE8#, POE10# input level detection	GPT2ABZE· ((POE11F•POE11E) + (GPT23HIZ) + (ICU.NMISR.OSTST) + (CMADDGPT23ZE· S12AD.ADCMPSEL.POE· (S12AD.ADCMPFR.CnFLAG)) + (IC1ADDGPT23ZE•POE0F) + (IC2ADDGPT23ZE•POE4F) + (IC3ADDGPT23ZE•POE8E•POE8F) + (IC4DDGPT23ZE•POE10E•POE10F)) (n = 0 to 2, 4 to 6)
GPT3 pins (GTIOC3A and GTIOC3B)	• POE11# input level detection • SPOER setting • Detection of stopped oscillation • Additional conditions of the POECR6 – 12-bit A/D converter comparator detection – POE0#, POE4#, POE8#, POE10# input level detection	GPT3ABZE? ((POE11F•POE11E) + (GPT23HIZ) + (ICU.NMISR.OSTST) + (CMADDGPT23ZE· S12AD.ADCMPSEL.POE· (S12AD.ADCMPFR.CnFLAG)) + (IC1ADDGPT23ZE•POE0F) + (IC2ADDGPT23ZE•POE4F) + (IC3ADDGPT23ZE•POE8E•POE8F) + (IC4ADDGPT23ZE•POE10E•POE10F)) (n = 0 to 2, 4 to 6)

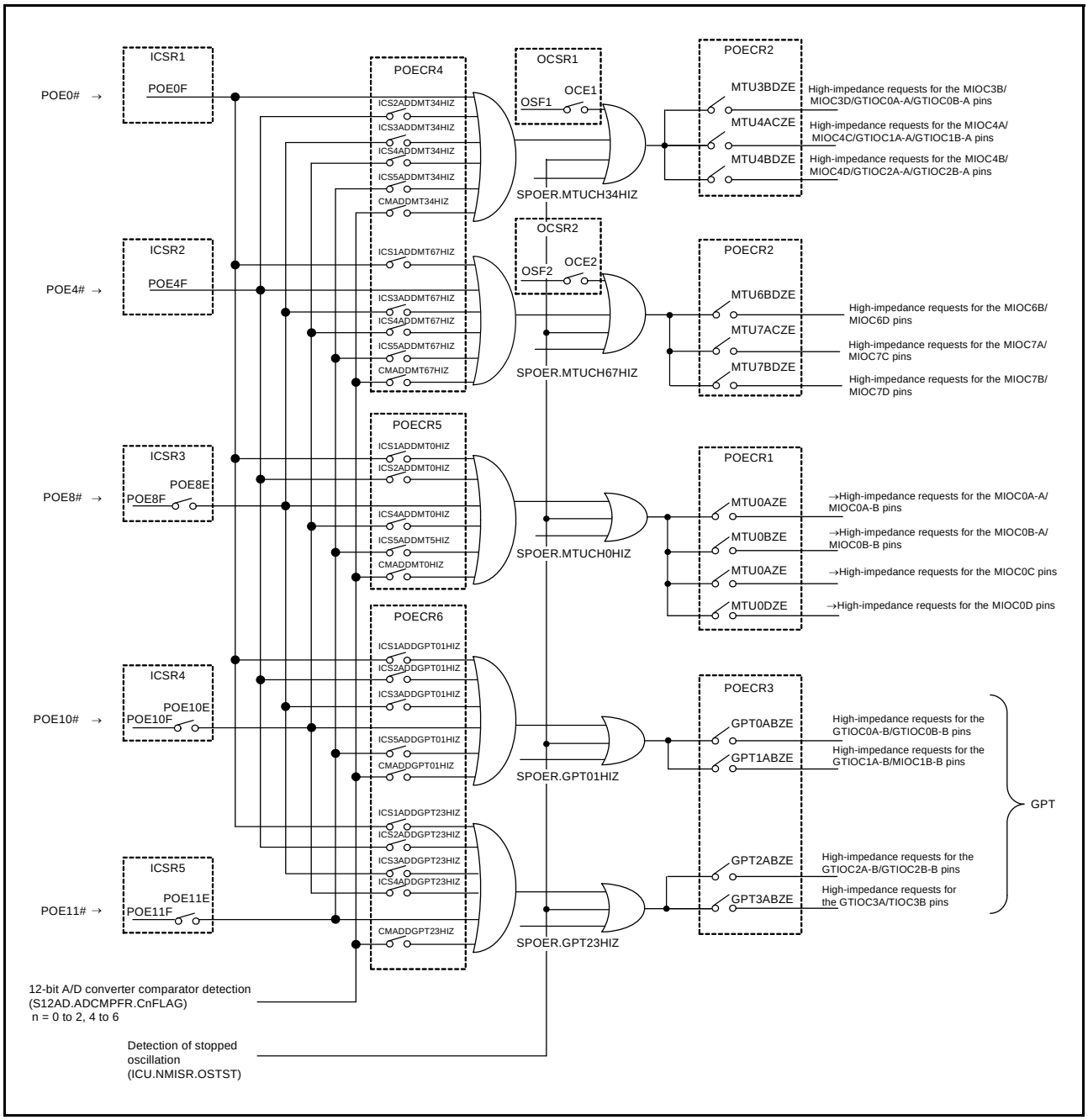


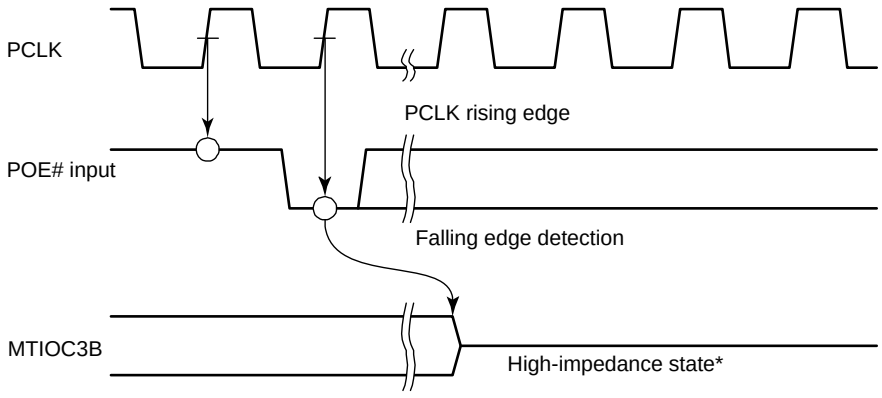
Figure 17.2 Target Pins and Conditions for High-Impedance Control

17.3.1 Input Level Detection Operation

If the input conditions set by ICSR1 to ICSR5 occur on the POE0#, POE4#, POE8#, POE10#, and POE11# pins, the MTU3, MTU4 and MTU6 and MTU7 pins for the MTU complementary PWM output, and MTU0 pins, and GPT pins are placed in high-impedance state. Note however, that these pins are still placed in the high-impedance state even when the GPT and MTU3 functions are not selected for the pins.

(1) Falling Edge Detection

When a change from a high to low level is input to the POE0#, POE4#, POE8#, POE10#, and POE11# pins, the pins for the MTU complementary PWM output, and MTU0 pins, and pin functions multiplexed with the GPT pins are placed in high-impedance state. Figure 17.3 shows a sample timing after the level changes in input to the POE0#, POE4#, POE8#, POE10#, and POE11# pins until the respective pins enter high-impedance state.



Note: * The other pins also enter the high-impedance state in the similar timing.

Figure 17.3 Falling Edge Detection

(2) Low-Level Detection

Figure 17.4 shows the low-level detection operation. Sixteen continuous low levels are sampled with the sampling clock selected by ICSR1 to ICSR5. If even one high level is detected during this interval, the low level is not accepted.
The timing when pins for the MTU complementary PWM output, and MTU0 pins and GPT pins enter the high-impedance state after the sampling clock is input is the same in both falling-edge detection and in low-level detection.

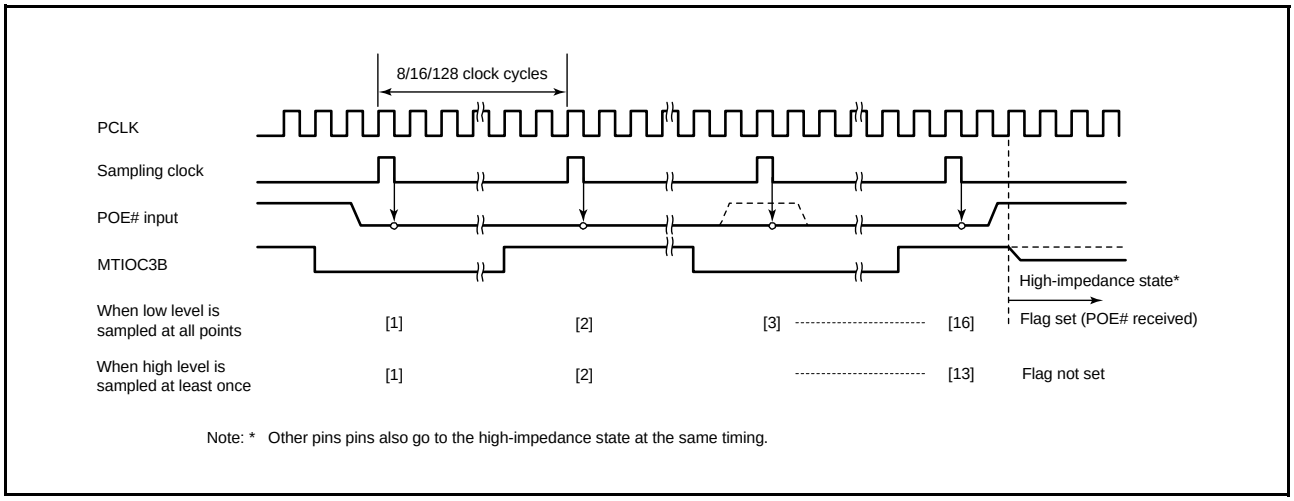


Figure 17.4 Low-Level Detection Operation

17.3.2 Output-Level Compare Operation

Figure 17.5 shows an example of the output-level compare operation for the combination of MTIOC3B and MTIOC3D. The operation is the same for the other pin combinations.

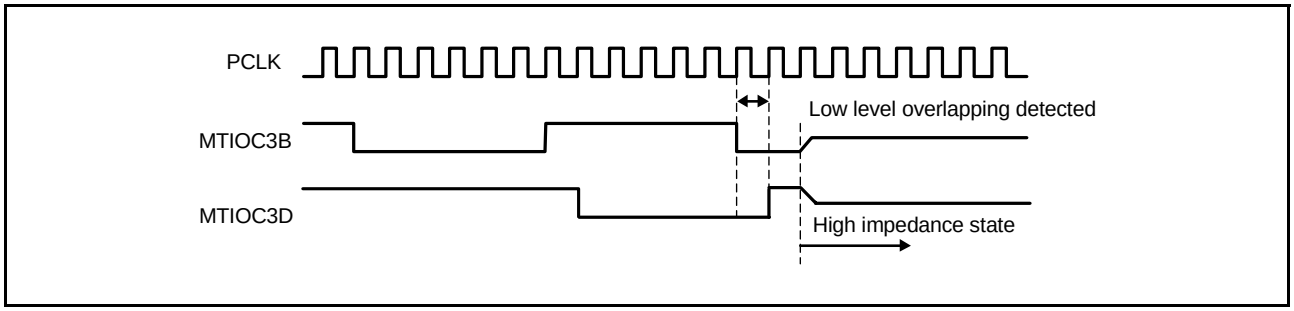


Figure 17.5 Output-Level Compare Operation

17.3.3 High-Impedance Control Using Registers

The high-impedance state of the MTU pins (MTU0, MTU3, MTU4, MTU6, and MTU7) and the GPT pins can be directly controlled by using the software port output enable register (SPOER).
For instance, setting the CH34HIZ bit in SPOER to 1 places the MTU3 and MTU4 pins specified by port output enable control register 2 (POECR2) in the high-impedance state.
The high-impedance state of other pins can also be controlled by setting the appropriate bits in SPOER.

17.3.4 High-Impedance Control through Detection of Stopped Oscillation

When the oscillation-stop detection circuit in the clock pulse generator detects stopped oscillation, the MTU3, MTU4, MTU6, and MTU7 pins if specified in the port output enable control register 2 (POECR2), the MTU0 pins if specified in the port output enable control register 1 (POECR1), and the GPT pin if specified by the port enable register 3(POECR3), can be placed in the high-impedance state.

17.3.5 High-impedance Control through Detection of the Comparator

The MTU complementary PWM output pins, MTU0 pin, and the GPT pins can be placed in the high-impedance state in response to detection by the comparator within the 12-bit A/D converter.
For instance, adding the CjFLAG (j is 0 to 2, and 4 to 6) flags in the ACMPFR of the S12ADA to the control conditions for the high-impedance state of the MTU3 and MTU4 pins by setting the CMADDMT34ZE bit in the POECR4 register after specifying the MTU3 and MTU4 pins in port output enable control register 2 (POECR2) leads to the pins being placed in the high-impedance state on comparator detection.
The high-impedance state of other pins can also be controlled by setting the appropriate bits in the POECR1 to POECR6.

17.3.6 Additional Functions for Controlling High-Impedance States

Settings in port enable registers 4 to 6 (POECR4 to POECR6) can add further high-impedance control conditions for the MTU complementary PWM output, MTU0, and GPT pins.
For instance, the settings listed below can be added as high-impedance control conditions for the MTU3 and MTU4 pins.

- Setting the CMADDMT34ZE bit in POECR4 to 1 adds comparator detection
- Setting the IC2ADDMT34ZE bit in POECR4 to 1 adds detection of the input level on the POE4# pin
- Setting the IC3ADDMT34ZE bit in POECR4 to 1 and adds the input level detection by the POE8#
- Setting the IC4ADDMT34ZE bit in POECR4 to 1 and adds the input level detection by the POE10#
- Setting the IC5ADDMT34ZE bit in POECR4 to 1 and adds the input level detection by the POE11#

The high-impedance state of other pins can also be controlled by setting the appropriate bits in the POECR4 to POECR6.

17.3.7 Release from High-Impedance State

MTU pins which have entered high-impedance state due to input-level detection can be released from the state either by returning them to their initial state with a reset, or by clearing all of the POE0#, POE4#, POE8#, POE10#, and POE11# flags in ICSR1 to ICSR5. However, note that when low-level sampling is selected with the POE0M[1:0], POE4M[1:0], POE8M[1:0], POE10M[1:0], and POE11M[1:0] bits in ICSR1 to ICSR5, just writing 0 to a flag is ignored (the flag is not cleared); flags can be cleared by writing 0 to it only after a high level is input to the POE0#, POE4#, POE8#, POE10#, and POE11# pins and is sampled.

MTU pins which have entered high-impedance state due to output-level detection can be released from the state either by returning them to their initial state with a reset, or by clearing the OCF1 and OCF2 flags in OCSR1 and OCSR2, respectively. However, note that just writing 0 to a flag is ignored (the flag is not cleared); flags can be cleared only after an inactive level is output from the MTU complementary PWM pins. Inactive-level outputs can be achieved by setting the MTU3, GPT, and ALR1 registers.

MTU pins which have entered high-impedance state due to comparator detection can be released from the state either by returning them to their initial state with a reset, or by clearing the ICSR1.POE0F, ICSR2.POE4F, ICSR3.POE8F, ICSR4.POE10F, and ICSR5.POE11F flags, and furthermore, S12AD.ADCMPFR.CnFLAG (n = 0 to 2, or 4 to 6) flags, respectively. However, note that just writing 0 to a flag is ignored (the flag is not cleared); flags can be cleared only when the inputs are in the specified range by the comparator.

17.4 Interrupts

The POE3 issues a request to generate an interrupt when the specified condition is satisfied during input level detection or output level comparison. Table 17.6 shows the interrupt sources and their conditions.

Table 17.6 Interrupt Sources and Conditions

Name	Interrupt Source	Interrupt Flag	Condition
OEI1	Output enable interrupt 1	POE0F and OSF1	PIE1•POE0F + OIE1•OSF1
OEI2	Output enable interrupt 2	POE4F and OSF2	PIE2•POE4F + OIE2•OSF2
OEI3	Output enable interrupt 3	POE8F	PIE3•POE8F
OEI4	Output enable interrupt 4	POE10F and POE11F	PIE4•POE10F + PIE5•POE11F

17.5 Usage Notes

When the POE3 is used, do not make a transition to software standby mode or deep software standby mode. In these modes, the POE3 stops and thus the high-impedance state of pins cannot be controlled.

18. General PWM Timer (GPT)

The RX62T Group has a general PWM timer (GPT) consisting of a four-channel 16-bit timer. The GPT operates at a maximum of 100 MHz.

18.1 Overview

Table 18.1 lists the specifications for the GPT, and Table 18.2 shows the functions of the GPT. Figure 18.1 shows a block diagram of the GPT.

Table 18.1 Specifications of GPT

Item	Description
Function	• 16 bits × 4 channels • Up-count or down-count operation (saw waves) or up/down-count operation (triangle waves) for each counter. • Clock sources independently selectable for each channel • Two input/output pins per channel • Two output compare/input capture registers per channel • For the two output compare/input capture registers of each channel, four registers are provided as buffer registers and are capable of operating as comparison registers when buffering is not in use. • In output compare operation, buffer switching can be at crests or troughs, enabling the generation of laterally asymmetric PWM waveforms. • Registers for setting up frame cycles in each channel (with capability for generating interrupts at overflow or underflow) • Synchronizable operation of the several counters • Modes of synchronized operation (synchronized, or displaced by desired times for phase shifting) • Generation of dead times in PWM operation • Through combination of three counters, generation of three-phase PWM waveforms incorporating dead times • Starting, clearing, and stopping counters in response to external or internal triggers • Internal trigger sources: output of the comparator detection, software, and compare match • The frequency-divided system clock (ICLK) can be used as a counter clock for measuring timing of the edges of signals produced by frequency-dividing the IWDT-dedicated low-speed on-chip oscillator clock signal (to detect abnormal oscillation).

Table 18.2 Functions of GPT (1 / 2)

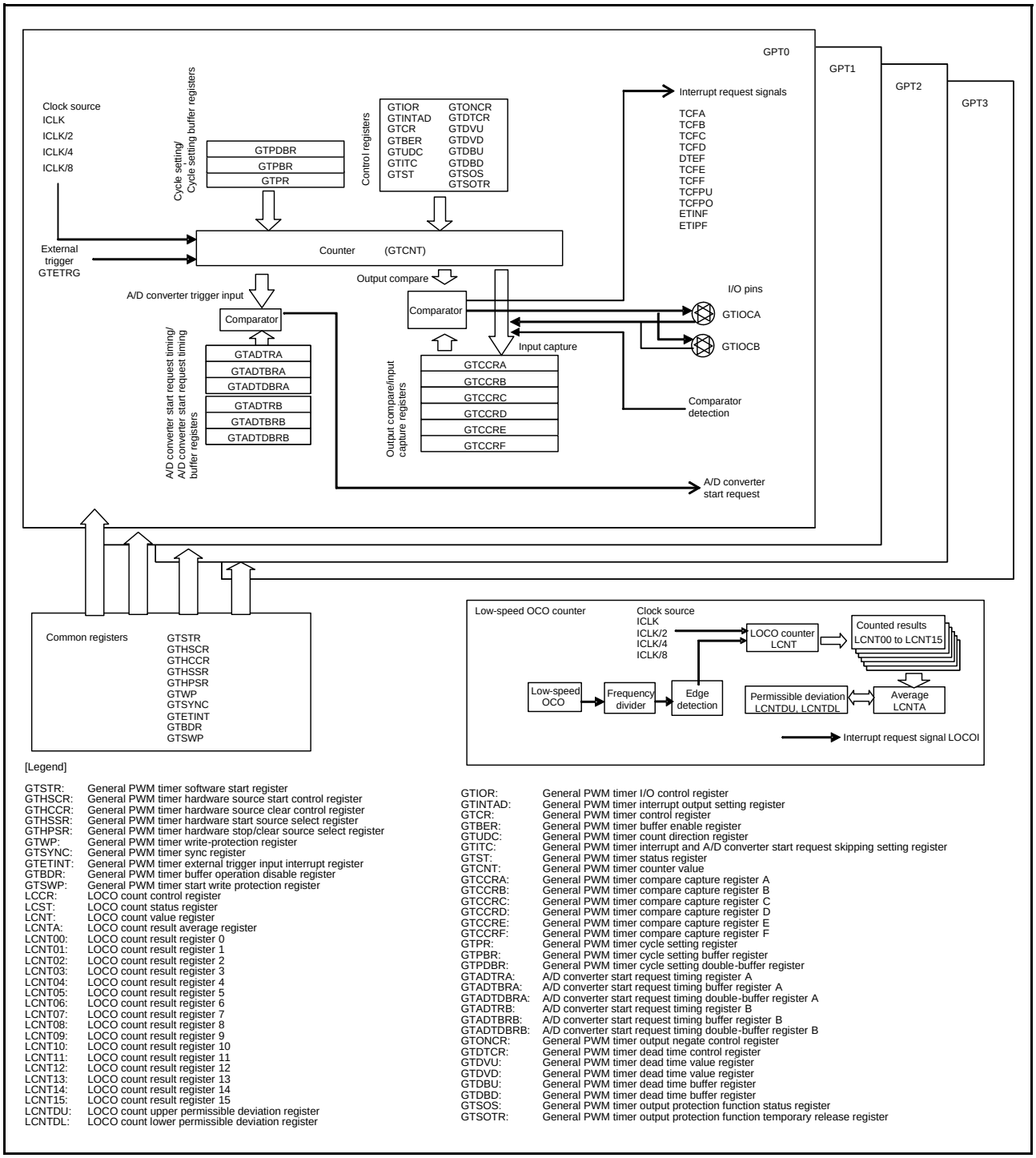
Item		GPT0	GPT1	GPT2	GPT3
Count clock		ICLK ICLK/2 ICLK/4 ICLK/8	ICLK ICLK/2 ICLK/4 ICLK/8	ICLK ICLK/2 ICLK/4 ICLK/8	ICLK ICLK/2 ICLK/4 ICLK/8
Output compare/input capture registers (GTCCR)		GTCCRA GTCCRB	GTCCRA GTCCRB	GTCCRA GTCCRB	GTCCRA GTCCRB
Compare/buffer registers		GTCCRC GTCCRD GTCCRE GTCCRF	GTCCRC GTCCRD GTCCRE GTCCRF	GTCCRC GTCCRD GTCCRE GTCCRF	GTCCRC GTCCRD GTCCRE GTCCRF
Cycle setting register		GTPR	GTPR	GTPR	GTPR
Cycle setting buffer registers		GTPBR GTPDBR	GTPBR GTPDBR	GTPBR GTPDBR	GTPBR GTPDBR
I/O pins		GTIOC0A GTIOC0B	GTIOC1A GTIOC1B	GTIOC2A GTIOC2B	GTIOC3A GTIOC3B
External trigger input pin		GTETRG			
Counter clear sources		GTPR compare match, input capture, comparator detection, GTETRG pin input, GTIOC3A/GTIOC3B pin input, and GTIOC3A/GTIOC3B internal output (output compare)			
Compare match output	Low output	√	√	√	√
	High output	√	√	√	√
	Toggle output	√	√	√	√
Input capture function		√	√	√	√
Synchronized operation		√	√	√	√
Phase shift start		√	√	√	√
Automatic addition of dead time		√	√	√	√
PWM mode		√	√	√	√
Buffer operation		√	√	√	√
One-shot operation		√	√	√	√
DTC activation		All the interrupt sources			
A/D converter start trigger		Compare match of GTADTRA or GTADTRB	Compare match of GTADTRA or GTADTRB	Compare match of GTADTRA or GTADTRB	Compare match of GTADTRA or GTADTRB
Interrupt sources		Five sources • GTCCRA compare match/input capture (GTCIA0) • GTCCRB compare match/input capture (GTCIB0) • GTCCRC compare match/GTCCRD compare match/dead time error (GTCIC0) • GTCCRE compare match/GTCCRF compare match (GTCIE0) • GTCNT overflow (GTPR compare match)/GTCNT undervlow (GTCIV0)	Five sources • GTCCRA compare match/input capture (GTCIA1) • GTCCRB compare match/input capture (GTCIB1) • GTCCRC compare match/GTCCRD compare match/dead time error (GTCIC1) • GTCCRE compare match/GTCCRF compare match (GTCIE1) • GTCNT overflow (GTPR compare match)/GTCNT undervlow (GTCIV1)	Five sources • GTCCRA compare match/input capture (GTCIA2) • GTCCRB compare match/input capture (GTCIB2) • GTCCRC compare match/GTCCRD compare match/dead time error (GTCIC2) • GTCCRE compare match/GTCCRF compare match (GTCIE2) • GTCNT overflow (GTPR compare match)/GTCNT undervlow (GTCIV2)	Five sources • GTCCRA compare match/input capture (GTCIA3) • GTCCRB compare match/input capture (GTCIB3) • GTCCRC compare match/GTCCRD compare match/dead time error (GTCIC3) • GTCCRE compare match/GTCCRF compare match (GTCIE3) • GTCNT overflow (GTPR compare match)/GTCNT undervlow (GTCIV3)
Common interrupt source		External trigger/LOCO count function interrupt (LOCOI)			

Table 18.2 Functions of GPT (2 / 2)

Item	GPT0	GPT1	GPT2	GPT3
Interrupt skipping function	Skips GTCNT overflows (GTPR compare match)/ GTCNT underflow (GTCIV0) interrupts (with interlocking function for other interrupts or A/D conversion requests).	Skips GTCNT overflows (GTPR compare match)/ GTCNT underflow (GTCIV1) interrupts (with interlocking function for other interrupts or A/D conversion requests).	Skips GTCNT overflows (GTPR compare match)/ GTCNT underflow (GTCIV2) interrupts (with interlocking function for other interrupts or A/D conversion requests).	Skips GTCNT overflows (GTPR compare match)/ GTCNT underflow (GTCIV3) interrupts (with interlocking function for other interrupts or A/D conversion requests).

√: Possible

—: Not possible



[Legend]

GTSTR: General PWM timer software start register
GTHSCR: General PWM timer hardware source start control register
GTHCCR: General PWM timer hardware source clear control register
GTHSSR: General PWM timer hardware start source select register
GTHPSR: General PWM timer hardware stop/clear source select register
GTWP: General PWM timer write-protection register
GTSYNC: General PWM timer sync register
GTETINT: General PWM timer external trigger input interrupt register
GTBDR: General PWM timer buffer operation disable register
GTSWP: General PWM timer start write protection register
LCCR: LOCO count control register
LCST: LOCO count status register
LCNT: LOCO count value register
LCNTA: LOCO count result average register
LCNT00: LOCO count result register 0
LCNT01: LOCO count result register 1
LCNT02: LOCO count result register 2
LCNT03: LOCO count result register 3
LCNT04: LOCO count result register 4
LCNT05: LOCO count result register 5
LCNT06: LOCO count result register 6
LCNT07: LOCO count result register 7
LCNT08: LOCO count result register 8
LCNT09: LOCO count result register 9
LCNT10: LOCO count result register 10
LCNT11: LOCO count result register 11
LCNT12: LOCO count result register 12
LCNT13: LOCO count result register 13
LCNT14: LOCO count result register 14
LCNT15: LOCO count result register 15
LCNTDU: LOCO count upper permissible deviation register
LCNTDL: LOCO count lower permissible deviation register

GTIOR: General PWM timer I/O control register
GTINTAD: General PWM timer interrupt output setting register
GTCR: General PWM timer control register
GTBER: General PWM timer buffer enable register
GTUDC: General PWM timer count direction register
GTITC: General PWM timer interrupt and A/D converter start request skipping setting register
GTST: General PWM timer status register
GTCNT: General PWM timer counter value
GTCCRA: General PWM timer compare capture register A
GTCCRB: General PWM timer compare capture register B
GTCCRC: General PWM timer compare capture register C
GTCCRD: General PWM timer compare capture register D
GTCCRE: General PWM timer compare capture register E
GTCCRF: General PWM timer compare capture register F
GTPR: General PWM timer cycle setting register
GTPBR: General PWM timer cycle setting buffer register
GTPDBR: General PWM timer cycle setting double-buffer register
GTADTRA: A/D converter start request timing register A
GTADTBRA: A/D converter start request timing buffer register A
GTADTDBRA: A/D converter start request timing double-buffer register A
GTADTRB: A/D converter start request timing register B
GTADTBRB: A/D converter start request timing buffer register B
GTADTDBRB: A/D converter start request timing double-buffer register B
GTONCR: General PWM timer output negate control register
GTDTCR: General PWM timer dead time control register
GTDVU: General PWM timer dead time value register
GTDVD: General PWM timer dead time value register
GTDBU: General PWM timer dead time buffer register
GTDBD: General PWM timer dead time buffer register
GTSOS: General PWM timer output protection function status register
GTSOTR: General PWM timer output protection function temporary release register

Figure 18.1 Block Diagram of GPT

Table 18.3 lists the I/O pins used in the GPT.

Table 18.3 I/O Pins of GPT

Channel	Pin Name	I/O	Function
GPT	GTETRG	Input	External trigger input pin
GPT0	GTIOC0A	I/O	GTCCRA input capture input/output compare output/PWM output pin
	GTIOC0B	I/O	GTCCRB input capture input/output compare output/PWM output pin
GPT1	GTIOC1A	I/O	GTCCRA input capture input/output compare output/PWM output pin
	GTIOC1B	I/O	GTCCRB input capture input/output compare output/PWM output pin
GPT2	GTIOC2A	I/O	GTCCRA input capture input/output compare output/PWM output pin
	GTIOC2B	I/O	GTCCRB input capture input/output compare output/PWM output pin
GPT3	GTIOC3A	I/O	GTCCRA input capture input/output compare output/PWM output pin
	GTIOC3B	I/O	GTCCRB input capture input/output compare output/PWM output pin

18.2 Register Descriptions

Table 18.4 lists the registers of the GPT.

Table 18.4 Registers of GPT (1 / 5)

Channel	Register Name	Symbol	Value after Reset	Address	Access Size
GPT	General PWM timer software start register	GTSTR	0000h	000C 2000h	8, 16, 32
	General PWM timer hardware source start control register	GTHSCR	0000h	000C 2004h	8, 16, 32
	General PWM timer hardware source clear control register	GTHCCR	0000h	000C 2006h	8, 16, 32
	General PWM timer hardware start source select register	GTHSSR	0000h	000C 2008h	8, 16, 32
	General PWM timer hardware stop/clear source select register	GTHPSR	0000h	000C 200Ah	8, 16, 32
	General PWM timer write-protection register	GTWP	0000h	000C 200Ch	8, 16, 32
	General PWM timer sync register	GTSYNC	0000h	000C 200Eh	8, 16, 32
	General PWM timer external trigger input interrupt register	GTETINT	0000h	000C 2010h	8, 16, 32
	General PWM timer buffer operation disable register	GTBDR	0000h	000C 2014h	8, 16, 32
	General PWM timer start write protection register	GTSWP	0000h	000C 2018h	8, 16, 32
	LOCO count control register	LCCR	0000h	000C 2080h	8, 16, 32
	LOCO count status register	LCST	0000h	000C 2082h	8, 16, 32
	LOCO count value register	LCNT	0000h	000C 2084h	8, 16, 32
	LOCO count result average register	LCNTA	0000h	000C 2086h	8, 16, 32
	LOCO count result register 0	LCNT00	0000h	000C 2088h	8, 16, 32
	LOCO count result register 1	LCNT01	0000h	000C 208Ah	8, 16, 32
	LOCO count result register 2	LCNT02	0000h	000C 208Ch	8, 16, 32
	LOCO count result register 3	LCNT03	0000h	000C 208Eh	8, 16, 32
	LOCO count result register 4	LCNT04	0000h	000C 2090h	8, 16, 32
	LOCO count result register 5	LCNT05	0000h	000C 2092h	8, 16, 32
	LOCO count result register 6	LCNT06	0000h	000C 2094h	8, 16, 32
	LOCO count result register 7	LCNT07	0000h	000C 2096h	8, 16, 32
	LOCO count result register 8	LCNT08	0000h	'000C 2098h	8, 16, 32
	LOCO count result register 9	LCNT09	0000h	000C 209Ah	8, 16, 32
	LOCO count result register 10	LCNT10	0000h	000C 209Ch	8, 16, 32
	LOCO count result register 11	LCNT11	0000h	000C 209Eh	8, 16, 32
	LOCO count result register 12	LCNT12	0000h	000C 20A0h	8, 16, 32
	LOCO count result register 13	LCNT13	0000h	000C 20A2h	8, 16, 32
	LOCO count result register 14	LCNT14	0000h	000C 20A4h	8, 16, 32
	LOCO count result register 15	LCNT15	0000h	000C 20A6h	8, 16, 32
	LOCO count upper permissible deviation register	LCNTDU	FFFFh	000C 20A8h	8, 16, 32
	LOCO count lower permissible deviation register	LCNTDL	FFFFh	000C 20AAh	8, 16, 32

Table 18.4 Registers of GPT (2 / 5)

Channel	Register Name	Symbol	Value after Reset	Address	Access Size
GPT0	General PWM timer I/O control register	GTIOR	0000h	000C 2100h	8, 16, 32
	General PWM timer interrupt output setting register	GTINTAD	0000h	000C 2102h	8, 16, 32
	General PWM timer control register	GTCR	0000h	000C 2104h	8, 16, 32
	General PWM timer buffer enable register	GTBER	0000h	000C 2106h	8, 16, 32
	General PWM timer count direction register	GTUDC	0001h	000C 2108h	8, 16, 32
	General PWM timer interrupt and A/D converter start request skipping setting register	GTITC	0000h	000C 210Ah	8, 16, 32
	General PWM timer status register	GTST	8000h	000C 210Ch	8, 16, 32
GPT0	General PWM timer counter	GTCNT	0000h	000C 210Eh	16
	General PWM timer compare capture register A	GTCCRA	FFFFh	000C 2110h	16, 32
	General PWM timer compare capture register B	GTCCRB	FFFFh	000C 2112h	16, 32
	General PWM timer compare capture register C	GTCCRC	FFFFh	000C 2114h	16, 32
	General PWM timer compare capture register D	GTCCRD	FFFFh	000C 2116h	16, 32
	General PWM timer compare capture register E	GTCCRE	FFFFh	000C 2118h	16, 32
	General PWM timer compare capture register F	GTCCRF	FFFFh	000C 211Ah	16, 32
	General PWM timer cycle setting register	GTPR	FFFFh	000C 211Ch	16, 32
	General PWM timer cycle setting buffer register	GTPBR	FFFFh	000C 211Eh	16, 32
	General PWM timer cycle setting double-buffer register	GTPDBR	FFFFh	000C 2120h	16, 32
	A/D converter start request timing register A	GTADTRA	FFFFh	000C 2124h	16, 32
	A/D converter start request timing buffer register A	GTADTBRA	FFFFh	000C 2126h	16, 32
	A/D converter start request timing double-buffer register A	GTADTDBRA	FFFFh	000C 2128h	16, 32
	A/D converter start request timing register B	GTADTRB	FFFFh	000C 212Ch	16, 32
	A/D converter start request timing buffer register B	GTADTBRB	FFFFh	000C 212Eh	16, 32
	A/D converter start request timing double-buffer register B	GTADTDBRB	FFFFh	000C 2130h	16, 32
	General PWM timer output negate control register	GTONCR	0100h	000C 2134h	16, 32
	General PWM timer dead time control register	GTDTCR	0000h	000C 2136h	16, 32
	General PWM timer dead time value register U	GTDVU	FFFFh	000C 2138h	16, 32
	General PWM timer dead time value register D	GTDVD	FFFFh	000C 213Ah	16, 32
	General PWM timer dead time buffer register U	GTDBU	FFFFh	000C 213Ch	16, 32
	General PWM timer dead time buffer register D	GTDBD	FFFFh	000C 213Eh	16, 32
	General PWM timer output protection function status register	GTSOS	0x00h	000C 2140h	16, 32
	General PWM timer output protection function temporary release register	GTSOTR	0000h	000C 2142h	16, 32

Table 18.4 Registers of GPT (3 / 5)

Channel	Register Name	Symbol	Value after Reset	Address	Access Size
GPT1	General PWM timer I/O control register	GTIOR	0000h	000C 2180h	8, 16, 32
	General PWM timer interrupt output setting register	GTINTAD	0000h	000C 2182h	8, 16, 32
	General PWM timer control register	GTCR	0000h	000C 2184h	8, 16, 32
	General PWM timer buffer enable register	GTBER	0000h	000C 2186h	8, 16, 32
	General PWM timer count direction register	GTUDC	0001h	000C 2188h	8, 16, 32
	General PWM timer interrupt and A/D converter start request skipping setting register	GTITC	0000h	000C 218Ah	8, 16, 32
	General PWM timer status register	GTST	8000h	000C 218Ch	8, 16, 32
	General PWM timer counter	GTCNT	0000h	000C 218Eh	16
	General PWM timer compare capture register A	GTCCRA	FFFFh	000C 2190h	16, 32
	General PWM timer compare capture register B	GTCCRB	FFFFh	000C 2192h	16, 32
	General PWM timer compare capture register C	GTCCRC	FFFFh	000C 2194h	16, 32
	General PWM timer compare capture register D	GTCCRD	FFFFh	000C 2196h	16, 32
	General PWM timer compare capture register E	GTCCRE	FFFFh	000C 2198h	16, 32
	General PWM timer compare capture register F	GTCCRF	FFFFh	000C 219Ah	16, 32
	General PWM timer cycle setting register	GTPR	FFFFh	000C 219Ch	16, 32
	General PWM timer cycle setting buffer register	GTPBR	FFFFh	000C 219Eh	16, 32
GPT1	General PWM timer cycle setting double-buffer register	GTPDBR	FFFFh	000C 21A0h	16, 32
	A/D converter start request timing register A	GTADTRA	FFFFh	000C 21A4h	16, 32
	A/D converter start request timing buffer register A	GTADTBRA	FFFFh	000C 21A6h	16, 32
	A/D converter start request timing double-buffer register A	GTADTDBRA	FFFFh	000C 21A8h	16, 32
	A/D converter start request timing register B	GTADTRB	FFFFh	000C 21ACh	16, 32
	A/D converter start request timing buffer register B	GTADTBRB	FFFFh	000C 21AEh	16, 32
	A/D converter start request timing double-buffer register B	GTADTDBRB	FFFFh	000C 21B0h	16, 32
	General PWM timer output negate control register	GTONCR	0100h	000C 21B4h	16, 32
	General PWM timer dead time control register	GTDTCR	0000h	000C 21B6h	16, 32
	General PWM timer dead time value register U	GTDVU	FFFFh	000C 21B8h	16, 32
	General PWM timer dead time value register D	GTDVD	FFFFh	000C 21BAh	16, 32
	General PWM timer dead time buffer register U	GTDBU	FFFFh	000C 21BCh	16, 32
	General PWM timer dead time buffer register D	GTDBD	FFFFh	000C 21BEh	16, 32
	General PWM timer output protection function status register	GTSOS	0x00h	000C 21C0h	16, 32
	General PWM timer output protection function temporary release register	GTSOTR	0000h	000C 21C2h	16, 32

Table 18.4 Registers of GPT (4 / 5)

Channel	Register Name	Symbol	Value after Reset	Address	Access Size
GPT2	General PWM timer I/O control register	GTIOR	0000h	000C 2200h	8, 16, 32
	General PWM timer interrupt output setting register	GTINTAD	0000h	000C 2202h	8, 16, 32
	General PWM timer control register	GTCR	0000h	000C 2204h	8, 16, 32
	General PWM timer buffer enable register	GTBER	0000h	000C 2206h	8, 16, 32
	General PWM timer count direction register	GTUDC	0001h	000C 2208h	8, 16, 32
	General PWM timer interrupt and A/D converter start request skipping setting register	GTITC	0000h	000C 220Ah	8, 16, 32
	General PWM timer status register	GTST	8000h	000C 220Ch	8, 16, 32
	General PWM timer counter	GTCNT	0000h	000C 220Eh	16
	General PWM timer compare capture register A	GTCCRA	FFFFh	000C 2210h	16, 32
	General PWM timer compare capture register B	GTCCRB	FFFFh	000C 2212h	16, 32
	General PWM timer compare capture register C	GTCCRC	FFFFh	000C 2214h	16, 32
	General PWM timer compare capture register D	GTCCRD	FFFFh	000C 2216h	16, 32
	General PWM timer compare capture register E	GTCCRE	FFFFh	000C 2218h	16, 32
	General PWM timer compare capture register F	GTCCRF	FFFFh	000C 221Ah	16, 32
	General PWM timer cycle setting register	GTPR	FFFFh	000C 221Ch	16, 32
	General PWM timer cycle setting buffer register	GTPBR	FFFFh	000C 221Eh	16, 32
	General PWM timer cycle setting double-buffer register	GTPDBR	FFFFh	000C 2220h	16, 32
	A/D converter start request timing register A	GTADTRA	FFFFh	000C 2224h	16, 32
	A/D converter start request timing buffer register A	GTADTBRA	FFFFh	000C 2226h	16, 32
	A/D converter start request timing double-buffer register A	GTADTDBRA	FFFFh	000C 2228h	16, 32
	A/D converter start request timing register B	GTADTRB	FFFFh	000C 222Ch	16, 32
	A/D converter start request timing buffer register B	GTADTBRB	FFFFh	000C 222Eh	16, 32
	A/D converter start request timing double-buffer register B	GTADTDBRB	FFFFh	000C 2230h	16, 32
	General PWM timer output negate control register	GTONCR	0100h	000C 2234h	16, 32
	General PWM timer dead time control register	GTDTCR	0000h	000C 2236h	16, 32
GPT2	General PWM timer dead time value register U	GTDVU	FFFFh	000C 2238h	16, 32
	General PWM timer dead time value register D	GTDVD	FFFFh	000C 223Ah	16, 32
	General PWM timer dead time buffer register U	GTDBU	FFFFh	000C 223Ch	16, 32
	General PWM timer dead time buffer register D	GTDBD	FFFFh	000C 223Eh	16, 32
	General PWM timer output protection function status register	GTSOS	0x00h	000C 2240h	16, 32
	General PWM timer output protection function temporary release register	GTSOTR	0000h	000C 2242h	16, 32

Table 18.4 Registers of GPT (5 / 5)

Channel	Register Name	Symbol	Value after Reset	Address	Access Size
GPT3	General PWM timer I/O control register	GTIOR	0000h	000C 2280h	8, 16, 32
	General PWM timer interrupt output setting register	GTINTAD	0000h	000C 2282h	8, 16, 32
	General PWM timer control register	GTCR	0000h	000C 2284h	8, 16, 32
	General PWM timer buffer enable register	GTBER	0000h	000C 2286h	8, 16, 32
	General PWM timer count direction register	GTUDC	0001h	000C 2288h	8, 16, 32
	General PWM timer interrupt and A/D converter start request skipping setting register	GTITC	0000h	000C 228Ah	8, 16, 32
	General PWM timer status register	GTST	8000h	000C 228Ch	8, 16, 32
	General PWM timer counter	GTCNT	0000h	000C 228Eh	16
	General PWM timer compare capture register A	GTCCRA	FFFFh	000C 2290h	16, 32
	General PWM timer compare capture register B	GTCCRB	FFFFh	000C 2292h	16, 32
	General PWM timer compare capture register C	GTCCRC	FFFFh	000C 2294h	16, 32
	General PWM timer compare capture register D	GTCCRD	FFFFh	000C 2296h	16, 32
	General PWM timer compare capture register E	GTCCRE	FFFFh	000C 2298h	16, 32
	General PWM timer compare capture register F	GTCCRF	FFFFh	000C 229Ah	16, 32
	General PWM timer cycle setting register	GTPR	FFFFh	000C 229Ch	16, 32
	General PWM timer cycle setting buffer register	GTPBR	FFFFh	000C 229Eh	16, 32
	General PWM timer cycle setting double-buffer register	GTPDBR	FFFFh	000C 22A0h	16, 32
	A/D converter start request timing register A	GTADTRA	FFFFh	000C 22A4h	16, 32
	A/D converter start request timing buffer register A	GTADTBRA	FFFFh	000C 22A6h	16, 32
	A/D converter start request timing double-buffer register A	GTADTDBRA	FFFFh	000C 22A8h	16, 32
	A/D converter start request timing register B	GTADTRB	FFFFh	000C 22ACh	16, 32
	A/D converter start request timing buffer register B	GTADTBRB	FFFFh	000C 22AEh	16, 32
	A/D converter start request timing double-buffer register B	GTADTDBRB	FFFFh	000C 22B0h	16, 32
	General PWM timer output negate control register	GTONCR	0100h	000C 22B4h	16, 32
	General PWM timer dead time control register	GTDTCR	0000h	000C 22B6h	16, 32
	General PWM timer dead time value register U	GTDVU	FFFFh	000C 22B8h	16, 32
	General PWM timer dead time value register D	GTDVD	FFFFh	000C 22BAh	16, 32
	General PWM timer dead time buffer register U	GTDBU	FFFFh	000C 22BCh	16, 32
	General PWM timer dead time buffer register D	GTDBD	FFFFh	000C 22BEh	16, 32
	General PWM timer output protection function status register	GTSOS	0x00h	000C 22C0h	16, 32
	General PWM timer output protection function temporary release register	GTSOTR	0000h	000C 22C2h	16, 32

18.2.1 General PWM Timer Software Start Register (GTSTR)

Address: 000C 2000h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	—	—	—	—	CST3	CST2	CST1	CST0
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	CST0	GPT0.GTCNT Count Start	0: Count operation is stopped 1: Count operation is performed	R/W
b1	CST1	GPT1.GTCNT Count Start		R/W
b2	CST2	GPT2.GTCNT Count Start		R/W
b3	CST3	GPT3.GTCNT Count Start		R/W
b15 to b4	—	Reserved	These bits are read as 0. The write value should be 0.	R/W

GTSTR starts or stops the GPTn.GTCNT counting operation (n = 0 to 3).

CSTn Bit (GPTn.GTCNT Count Start) (n = 0 to 3)

This bit starts or stops GPTn.GTCNT operation.

The counter operation can also be started or stopped by GTHSCR. When count operation is started by a hardware source, this bit is automatically set to 1, and when count operation is stopped by a hardware source, this bit is automatically cleared to 0.

18.2.2 General PWM Timer Hardware Source Start Control Register (GTHSCR)

Address: 000C 2004h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	CPHW3[1:0]		CPHW2[1:0]		CPHW1[1:0]		CPHW0[1:0]		CSHW3[1:0]		CSHW2[1:0]		CSHW1[1:0]		CSHW0[1:0]	
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1, b0	CSHW0[1:0]	GPT0.GTCNT Hardware Source Count Start	0 0: Count operation is not started by a hardware source. 0 1: Count operation is started at the rising edge of a hardware source. 1 0: Count operation is started at the falling edge of a hardware source. 1 1: Count operation is started at both rising and falling edges of a hardware source.	R/W
b3, b2	CSHW1[1:0]	GPT1.GTCNT Hardware Source Count Start		R/W
b5, b4	CSHW2[1:0]	GPT2.GTCNT Hardware Source Count Start		R/W
b7, b6	CSHW3[1:0]	GPT3.GTCNT Hardware Source Count Start		R/W
b9, b8	CPHW0[1:0]	GPT0.GTCNT Hardware Source Count Stop	0 0: Count operation is not stopped by a hardware source. 0 1: Count operation is stopped at the rising edge of a hardware source. 1 0: Count operation is stopped at the falling edge of a hardware source. 1 1: Count operation is stopped at both rising and falling edges of a hardware source.	R/W
b11, b10	CPHW1[1:0]	GPT1.GTCNT Hardware Source Count Stop		R/W
b13, b12	CPHW2[1:0]	GPT2.GTCNT Hardware Source Count Stop		R/W
b15, b14	CPHW3[1:0]	GPT3.GTCNT Hardware Source Count Stop		R/W

GTHSCR starts or stops the GPTn.GTCNT counting operation by a hardware source (n = 0 to 3).
When starting and stopping of GPTn.GTCNT by a hardware source occur simultaneously, counter start is given priority.

CSHWn[1:0] Bits (GPTn.GTCNT Hardware Source Count Start) (n = 0 to 3)

GPTn.GTCNT counting is started by a hardware source.
When the count operation is started by a hardware source, the corresponding bit in GTSTR automatically becomes 1.
The hardware source can be selected by GTHSSR.

CPHWn[1:0] Bits (GPTn.GTCNT Hardware Source Count Stop) (n = 0 to 3)

GPTn.GTCNT counting is stopped by a hardware source.
When the count operation is stopped by a hardware source, the corresponding bit in GTSTR automatically becomes 0.
The hardware source can be selected by GTHPSR.

18.2.3 General PWM Timer Hardware Source Clear Control Register (GTHCCR)

Address: 000C 2006h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	CCSW3	CCSW2	CCSW1	CCSW0	CCHW3[1:0]		CCHW2[1:0]		CCHW1[1:0]		CCHW0[1:0]	
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1, b0	CCHW0[1:0]	GPT0.GTCNT Hardware Source Counter Clear	0 0: Counter is not cleared by a hardware source. 0 1: Counter is cleared at the rising edge of a hardware source. 1 0: Counter is cleared at the falling edge of a hardware source. 1 1: Counter is cleared at both rising and falling edges of a hardware source.	R/W
b3, b2	CCHW1[1:0]	GPT1.GTCNT Hardware Source Counter Clear		R/W
b5, b4	CCHW2[1:0]	GPT2.GTCNT Hardware Source Counter Clear		R/W
b7, b6	CCHW3[1:0]	GPT3.GTCNT Hardware Source Counter Clear		R/W
b8	CCSW0	GPT0.GTCNT Counter Clear	When 1 is written to this bit, the counter is cleared. This bit automatically returns to 0 after the writing of 1. These bits are read as 0.	R/W
b9	CCSW1	GPT1.GTCNT Counter Clear		R/W
b10	CCSW2	GPT2.GTCNT Counter Clear		R/W
b11	CCSW3	GPT3.GTCNT Counter Clear		R/W
b15 to b12	—	Reserved	These bits are read as 0. The write value should be 0.	R/W

GTHCCR sets clearing of GPTn.GTCNT by a hardware source (n = 0 to 3).
Once the clearing of GPTn.GTCNT counter by a hardware source is set, counter clearing by the hardware source is executed whether the GPTn.GTCNT count operation is performed (GTSTR.CTSn = 1; n = 0 to 3) or stopped (GTSTR.CSTn = 0, n = 0 to 3).

CCHWn[1:0] Bits (GPTn.GTCNT Hardware Source Count Clear) (n = 0 to 3)

GPTn.GTCNT is cleared by a hardware source.
The hardware source can be selected by GTHPSR.
When CCHWn[1:0] is 01b, 10b, or 11b, the hardware source can be accepted repeatedly.

CCSWn Bit (GPTn.GTCNT Counter Clear) (n = 0 to 3)

When 1 is written to this bit, the GPTn.GTCNT counter is cleared. This bit automatically returns to 0 after the writing of 1. This bit is always read as 0.

18.2.4 General PWM Timer Hardware Start Source Select Register (GTHSSR)

Address: 000C 2008h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	CSHSL3[3:0]				CSHSL2[3:0]				CSHSL1[3:0]				CSHSL0[3:0]			
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b3 to b0	CSHSL0[3:0]	GPT0.GTCNT Hardware Counter Start Source Select	b3 b0 0 0 0 0: AN000 comparator detection 0 0 0 1: AN001 comparator detection 0 0 1 0: AN002 comparator detection 0 0 1 1: Setting prohibited 0 1 0 0: AN100 comparator detection 0 1 0 1: AN101 comparator detection 0 1 1 0: AN102 comparator detection 0 1 1 1: Setting prohibited 1 0 0 0: GTIOC3A pin input 1 0 0 1: GTIOC3B pin input 1 0 1 0: GTIOC3A internal output*1(output compare) 1 0 1 1: GTIOC3B internal output*1(output compare) 1 1 0 0: GTETRG pin input Settings other than above are prohibited.	R/W
b7 to b4	CSHSL1[3:0]	GPT1.GTCNT Hardware Counter Start Source Select	b7 b4 0 0 0 0: AN000 comparator detection 0 0 0 1: AN001 comparator detection 0 0 1 0: AN002 comparator detection 0 0 1 1: Setting prohibited 0 1 0 0: AN100 comparator detection 0 1 0 1: AN101 comparator detection 0 1 1 0: AN102 comparator detection 0 1 1 1: Setting prohibited 1 0 0 0: GTIOC3A pin input 1 0 0 1: GTIOC3B pin input 1 0 1 0: GTIOC3A internal output*1(output compare) 1 0 1 1: GTIOC3B internal output*1(output compare) 1 1 0 0: GTETRG pin input Settings other than above are prohibited.	R/W
b11 to b8	CSHSL2[3:0]	GPT2.GTCNT Hardware Counter Start Source Select	b11 b8 0 0 0 0: AN000 comparator detection 0 0 0 1: AN001 comparator detection 0 0 1 0: AN002 comparator detection 0 0 1 1: Setting prohibited 0 1 0 0: AN100 comparator detection 0 1 0 1: AN101 comparator detection 0 1 1 0: AN102 comparator detection 0 1 1 1: Setting prohibited 1 0 0 0: GTIOC3A pin input 1 0 0 1: GTIOC3B pin input 1 0 1 0: GTIOC3A internal output*1(output compare) 1 0 1 1: GTIOC3B internal output*1(output compare) 1 1 0 0: GTETRG pin input Settings other than above are prohibited.	R/W

Bit	Symbol	Bit Name	Description	R/W
b15 to b12	CSHSL3[3:0]	GPT3.GTCNT Hardware Counter Start Source Select	b15 b12 0 0 0 0: AN000 comparator detection 0 0 0 1: AN001 comparator detection 0 0 1 0: AN002 comparator detection 0 0 1 1: Setting prohibited 0 1 0 0: AN100 comparator detection 0 1 0 1: AN101 comparator detection 0 1 1 0: AN102 comparator detection 0 1 1 1: Setting prohibited 1 0 0 0: GTIOC3A pin input 1 0 0 1: GTIOC3B pin input 1 0 1 0: Setting prohibited 1 0 1 1: Setting prohibited 1 1 0 0: GTETRG pin input Settings other than above are prohibited.	R/W

Note 1. Though the output pin is not available with the 80-pin and 64-pin products, such pin can be used as the source.

GTHSSR sets the hardware source to start GPTn.GTCNT (n = 0 to 3).
To change the source, clear the GTHSCR.CSHWn[1:0] bits to 0 before changing the source.

CSHSLn[3:0] Bits (GPTn.GTCNT Hardware Counter Start Source Select) (n = 0 to 3)

These bits select the hardware source to start GPTn.GTCNT.

Select 1000b as a hardware source with GPT3.GTIOR.GTIOA[5] = 0 and GPT3.GTONCR.OAE = 0. Select 1001b as a hardware source with GPT3.GTIOR.GTIOB[5] = 0 and GPT3.GTONCR.OBE¬ = 0.

18.2.5 General PWM Timer Hardware Stop/Clear Source Select Register (GTHPSR)

Address: 000C 200Ah

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	CSHPL3[3:0]				CSHPL2[3:0]				CSHPL1[3:0]				CSHPL0[3:0]			
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b3 to b0	CSHPL0[3:0]	GPT0.GTCNT Hardware Counter Stop/ Clear Source Select	b3 b0 0 0 0 0: AN000 comparator detection 0 0 0 1: AN001 comparator detection 0 0 1 0: AN002 comparator detection 0 0 1 1: Setting prohibited 0 1 0 0: AN100 comparator detection 0 1 0 1: AN101 comparator detection 0 1 1 0: AN102 comparator detection 0 1 1 1: Setting prohibited 1 0 0 0: GTIOC3A pin input 1 0 0 1: GTIOC3B pin input 1 0 1 0: GTIOC3A internal output (output compare) 1 0 1 1: GTIOC3B internal output (output compare) 1 1 0 0: GTETRG pin input Settings other than above are prohibited.	R/W
b7 to b4	CSHPL1[3:0]	GPT1.GTCNT Hardware Counter Stop/ Clear Source Select	b7 b4 0 0 0 0: AN000 comparator detection 0 0 0 1: AN001 comparator detection 0 0 1 0: AN002 comparator detection 0 0 1 1: Setting prohibited 0 1 0 0: AN100 comparator detection 0 1 0 1: AN101 comparator detection 0 1 1 0: AN102 comparator detection 0 1 1 1: Setting prohibited 1 0 0 0: GTIOC3A pin input 1 0 0 1: GTIOC3B pin input 1 0 1 0: GTIOC3A internal output (output compare) 1 0 1 1: GTIOC3B internal output (output compare) 1 1 0 0: GTETRG pin input Settings other than above are prohibited.	R/W
b11 to b8	CSHPL2[3:0]	GPT2.GTCNT Hardware Counter Stop/ Clear Source Select	b11 b8 0 0 0 0: AN000 comparator detection 0 0 0 1: AN001 comparator detection 0 0 1 0: AN002 comparator detection 0 0 1 1: Setting prohibited 0 1 0 0: AN100 comparator detection 0 1 0 1: AN101 comparator detection 0 1 1 0: AN102 comparator detection 0 1 1 1: Setting prohibited 1 0 0 0: GTIOC3A pin input 1 0 0 1: GTIOC3B pin input 1 0 1 0: GTIOC3A internal output (output compare) 1 0 1 1: GTIOC3B internal output (output compare) 1 1 0 0: GTETRG pin input Settings other than above are prohibited.	R/W

Bit	Symbol	Bit Name	Description	R/W
b15 to b12	CSHPL3[3:0]	GPT3.GTCNT Hardware Counter Stop/ Clear Source Select	b15 b12 0 0 0 0: AN000 comparator detection 0 0 0 1: AN001 comparator detection 0 0 1 0: AN002 comparator detection 0 0 1 1: Setting prohibited 0 1 0 0: AN100 comparator detection 0 1 0 1: AN101 comparator detection 0 1 1 0: AN102 comparator detection 0 1 1 1: Setting prohibited 1 0 0 0: GTIOC3A pin input 1 0 0 1: GTIOC3B pin input 1 0 1 0: Setting prohibited 1 0 1 1: Setting prohibited 1 1 0 0: GTETRG pin input Settings other than above are prohibited.	R/W

GTHPSR sets the hardware source to stop or clear GPTn.GTCNT (n = 0 to 3).
To change the source, clear the GTHSCR.CPHWn[1:0] bits and GTHCCR.CCHWn[1:0] bits to 0 before changing the source.

CSHPLn[3:0] Bits (GPTn.GTCNT Hardware Counter Stop/Clear Source Select) (n = 0 to 3)

These bits select the hardware source to stop or clear GPTn.GTCNT.

18.2.6 General PWM Timer Write-Protection Register (GTWP)

Address: 000C 200Ch

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	—	—	—	—	WP3	WP2	WP1	WP0
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	WP0	GPT0 Register Write Enable	0: Write to the register is enabled 1: Write to the register is disabled	R/W
b1	WP1	GPT1 Register Write Enable		R/W
b2	WP2	GPT2 Register Write Enable		R/W
b3	WP3	GPT3 Register Write Enable		R/W
b15 to b4	—	Reserved	These bits are read as 0. The write value should be 0.	R/W

GTWP enables or disables writing to registers to prevent accidental modification.

WPn Bit (GPTn Register Write Enable) (n = 0 to 3)

This bit enables or disables writing to GPTn registers.

18.2.7 General PWM Timer Sync Register (GTSYNC)

Address: 000C 200Eh

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	SYNC3[1:0]		—	—	SYNC2[1:0]		—	—	SYNC1[1:0]		—	—	SYNC0[1:0]	
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1, b0	SYNC0[1:0]	GPT0.GTCNT Counter Synchronized-Clear Source Select	b1 b0 0 0: GPT0.GTCNT is cleared by a GPT0 clearing source (synchronized clear is not performed). 0 1: GPT0.GTCNT is synchronously cleared by a GPT1 clearing source. 1 0: GPT0.GTCNT is synchronously cleared by a GPT2 clearing source. 1 1: GPT0.GTCNT is synchronously cleared by a GPT3 clearing source.	R/W
b3, b2	—	Reserved	These bits are read as 0. The write value should be 0.	R/W
b5, b4	SYNC1[1:0]	GPT1.GTCNT Counter Synchronized-Clear Source Select	b5 b4 0 0: GPT1.GTCNT is synchronously cleared by a GPT0 clearing source. 0 1: GPT1.GTCNT is cleared by a GPT1 clearing source (synchronized clear is not performed). 1 0: GPT1.GTCNT is synchronously cleared by a GPT2 clearing source. 1 1: GPT1.GTCNT is synchronously cleared by a GPT3 clearing source.	R/W
b7, b6	—	Reserved	These bits are read as 0. The write value should be 0.	R/W
b9, b8	SYNC2[1:0]	GPT2.GTCNT Counter Synchronized-Clear Source Select	b9 b8 0 0: GPT2.GTCNT is synchronously cleared by a GPT0 clearing source. 0 1: GPT2.GTCNT is synchronously cleared by a GPT1 clearing source. 1 0: GPT2.GTCNT is cleared by a GPT2 clearing source (synchronized clear is not performed). 1 1: GPT2.GTCNT is synchronously cleared by a GPT3 clearing source.	R/W
b11, b10	—	Reserved	These bits are read as 0. The write value should be 0.	R/W
b13, b12	SYNC3[1:0]	GPT3.GTCNT Counter Synchronized-Clear Source Select	b13 b12 0 0: GPT3.GTCNT is synchronously cleared by a GPT0 clearing source. 0 1: GPT3.GTCNT is synchronously cleared by a GPT1 clearing source. 1 0: GPT3.GTCNT is synchronously cleared by a GPT2 clearing source. 1 1: GPT3.GTCNT is cleared by a GPT3 clearing source (synchronized clear is not performed)	R/W
b15, b14	—	Reserved	These bits are read as 0. The write value should be 0.	R/W

GTSYNC sets the clearing source of the GPTn.GTCNT counter for synchronized clearing/synchronized operation. This register can be modified when count operation of GPTn.GTCNT is stopped (n = 0 to 3).

SYNCn[1:0] Bits (GPTn.GTCNT Counter Synchronized-Clear Source Select) (n = 0 to 3)

These bits select which channel's counter clearing source is used to clear GPTn.GTCNT. When setting the SYNCn[1:0] bits, first set the GPTn.GTCR.CCLR[1:0] bits to 11b (cleared by counter clearing in another channel performing synchronized clearing/synchronized operation).

18.2.8 General PWM Timer External Trigger Input Interrupt Register (GTETINT)

Address: 000C 2010h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	ETINF	ETIPF	—	—	—	—	—	—	ETINEN	ETIPEN
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	ETIPEN	External Trigger Rising Input Interrupt Request Enable	0: Interrupt request is disabled 1: Interrupt request is enabled	R/W
b1	ETINEN	External Trigger Falling Input Interrupt Request Enable	0: Interrupt request is disabled 1: Interrupt request is enabled	R/W
b7 to b2	—	Reserved	These bits are read as 0. The write value should be 0.	R/W
b8	ETIPF	External Trigger Rising Input Interrupt Request Flag	0: No interrupt request is generated 1: An interrupt request is generated	R/(W)*1
b9	ETINF	External Trigger Falling Input Interrupt Request Flag	0: No interrupt request is generated 1: An interrupt request is generated	R/(W)*1
b15 to b10	—	Reserved	These bits are read as 0. The write value should be 0.	R/W

Note 1. Only 0 can be written to clear the flag.

GTETINT enables or disables interrupts by the external trigger input pin (GTETRG). The interrupt request is generated as a LOCOI interrupt request.

ETIPEN Bit (External Trigger Rising Input Interrupt Request Enable)

This bit enables or disables an interrupt request generated at the rising edge of an external trigger input.

ETINEN Bit (External Trigger Falling Input Interrupt Request Enable)

This bit enables or disables an interrupt request generated at the falling edge of an external trigger input.

ETIPF Flag (External Trigger Rising Input Interrupt Request Flag)

This bit is a flag for an interrupt request generated at the rising edge of an external trigger input.
[Setting condition]

- An external trigger input rising edge has been detected.

[Clearing condition]

- 0 is written to this bit.

ETINF Flag (External Trigger Falling Input Interrupt Request Flag)

This bit is a flag for an interrupt request generated at the falling edge of an external trigger input.
[Setting condition]

- An external trigger input falling edge has been detected.

[Clearing condition]

- 0 is written to this bit.

18.2.9 General PWM Timer Buffer Operation Disable Register (GTBDR)

Address: 000C 2014h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	BD3[3]	BD3[2]	BD3[1]	BD3[0]	BD2[3]	BD2[2]	BD2[1]	BD2[0]	BD1[3]	BD1[2]	BD1[1]	BD1[0]	BD0[3]	BD0[2]	BD0[1]	BD0[0]
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	BD0[0]	GPT0.GTCCR Buffer Operation Disable	0: Buffer operation is enabled 1: Buffer operation is disabled	R/W
b1	BD0[1]	GPT0.GTPR Buffer Operation Disable		R/W
b2	BD0[2]	GPT0.GTADTRR Buffer Operation Disable		R/W
b3	BD0[3]	GPT0.GTDV Buffer Operation Disable		R/W
b4	BD1[0]	GPT1.GTCCR Buffer Operation Disable		R/W
b5	BD1[1]	GPT1.GTPR Buffer Operation Disable		R/W
b6	BD1[2]	GPT1.GTADTRR Buffer Operation Disable		R/W
b7	BD1[3]	GPT1.GTDV Buffer Operation Disable		R/W
b8	BD2[0]	GPT2.GTCCR Buffer Operation Disable		R/W
b9	BD2[1]	GPT2.GTPR Buffer Operation Disable		R/W
b10	BD2[2]	GPT2.GTADTRR Buffer Operation Disable		R/W
b11	BD2[3]	GPT2.GTDV Buffer Operation Disable		R/W
b12	BD3[0]	GPT3.GTCCR Buffer Operation Disable		R/W
b13	BD3[1]	GPT3.GTPR Buffer Operation Disable		R/W
b14	BD3[2]	GPT3.GTADTRR Buffer Operation Disable		R/W
b15	BD3[3]	GPT3.GTDV Buffer Operation Disable		R/W

GTBDR collectively enables or disables buffer operation of each channel. Even though a bit in GTBDR is set to 0 (buffer operation is enabled), buffer operation is not performed unless buffer operation is enabled by GTBER.

BDn[0] Bit (GPTn.GTCCR Buffer Operation Disable) (n = 0 to 3)

This bit disables buffer operation using GTCCRA, GTCCRC, and GTCCRD of GPTn together and buffer operation using GTCCRB, GTCCRE, and GTCCRF of GPTn together. When the GTIOCnA pin or GTIOCnB pin is used for input capture (GPTn.GTIOR.GTIOA[5] = 1 or GPTn.GTIOR.GTIOB[5] = 1), this bit must be set to 0.

BDn[1] Bit (GPTn.GTPR Buffer Operation Disable) (n = 0 to 3)

This bit disables buffer operation using GTPR, GTPBR, and GTPDBR of GPTn together.

BDn[2] Bit (GPTn.GTADTR Counter Buffer Operation Disable) (n = 0 to 3)

This bit disables buffer operation using GTADTRA, GTADTBRA, and GTADTDBRA of GPTn together and buffer operation using GTADTRB, GTADTBRB, and GTADTDBRB of GPTn together.

BDn[3] Bit (GPTn.GTDV Counter Buffer Operation Disable) (n = 0 to 3)

This bit disables buffer operation using GTDVU and GTDBU of GPTn together and buffer operation using GTDVD and GTDBD of GPTn together.

18.2.10 General PWM timer start write protection register (GTSWP)

Address: 000C 2018h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	—	—	—	—	SWP3	SWP2	SWP1	SWP0
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	SWP0	GTSTR.CST0 bit write protection	0: Writing to the register is enabled. 1: Writing to the register is disabled.	R/W
b1	SWP1	GTSTR.CST1 bit write protection		R/W
b2	SWP2	GTSTR.CST2 bit write protection		R/W
b3	SWP3	GTSTR.CST3 bit write protection		R/W
B15 to b4	—	Reserved	These bits are always read as 0. The write value should be 0.	R/W

The GTSWP register protects against erroneous writing by enabling or disabling writing to the GTSTR register.

SWPn Bits (GTSTR.CTSn Bit Write Protection Bit) (n = 0 to 3)

These bits enable and disable writing to the GTSTR.CSTn bits.

When the setting is “disabled”, writing to the GTSTR.CSTn bits is ignored.

However, if starting and stopping of counting by hardware sources is set in the GTHSCR register, the state of whether counting is in progress or stopped due to hardware sources is written to the GTSTR.CSTn bits even if the setting of the SWPn bits prohibits writing to the GTSTR.CSTn bits.

18.2.11 LOCO Count Control Register (LCCR)

Address: 000C 2080h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	LPSC[1:0]		TPSC[1:0]		LCNTAT	LCTO[2:0]			—	LCINTO	LCINTD	LCINTC	—	LCNTS	LCNTCR	LCNTE
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	LCNTE	LOCO Count Function Enable	0: LOCO count function is stopped 1: LOCO count function is operating	R/W
b1	LCNTCR	LOCO Count Value Clear	When 1 is written to this bit, the LCNT register is cleared. This bit automatically returns to 0 after the writing of 1. This bit is read as 0.	R/W
b2	LCNTS	LOCO Count Value Setting	When 1 is written to this bit, the LCNT00 value is set to LCNT01 to LCNT15 registers. This bit automatically returns to 0 after the writing of 1. This bit is read as 0.	R/W
b3	—	Reserved	This bit is read as 0. The write value should be 0.	R/W
b4	LCINTC	Frequency-Divided LOCO Clock Rise Interrupt Enable	0: Interrupt request is disabled 1: Interrupt request is enabled	R/W
b5	LCINTD	LOCO Count Value Deviation Exceedance Interrupt Enable	0: Interrupt request is disabled 1: Interrupt request is enabled	R/W
b6	LCINTO	LCNT Overflow Interrupt Enable	0: Interrupt request is disabled 1: Interrupt request is enabled	R/W
b7	—	Reserved	This bit is read as 0. The write value should be 0.	R/W
b10 to b8	LCTO[2:0]	Frequency-Divided LOCO Clock Rise Interrupt Skipping Count Setting	b10 b8 0 0 0: Skipping is not performed 0 0 1: Setting prohibited 0 1 0: Setting prohibited 0 1 1: Setting prohibited 1 0 0: Skipping count of 7 (counted once every 8 times) 1 0 1: Skipping count of 15 (counted once every 16 times) 1 1 0: Skipping count of 127 (counted once every 128 times) 1 1 1: Skipping count of 255 (counted once every 256 times)	R/W
b11	LCNTAT	LOCO Count Result Skipping Setting	0: Skipping is not performed 1: Skipping is performed	R/W
b13, b12	TPSC[1:0]	LOCO Count Clock Select	b13 b12 0 0: ICLK (system clock) 0 1: ICLK/2 (system clock/2) 1 0: ICLK/4 (system clock/4) 1 1: ICLK/8 (system clock/8)	R/W
b15, b14	LPSC[1:0]	Frequency-Divided LOCO Clock Select	b15 b14 0 0: 1 0 1: 1/16 1 0: 1/128 1 1: 1/256	R/W

LCCR sets the count function of the IWDT-dedicated low-speed on-chip oscillator (LOCO). When using the count function of the LOCO, also operate the independent watchdog timer (IWDT).

LCNTE Bit (LOCO Count Function Enable)

This bit starts or stops operation of the LOCO count function.

LCNTCR Bit (LOCO Count Value Clear)

This bit clears the LCNT register.
When 1 is written to this bit, the count value is cleared. This bit automatically returns to 0 after the writing of 1. This bit is read as 0.

LCNTS Bit (LOCO Count Value Setting)

This bit is used to set the LCNT00 register value to the LCNT01 to LCNT15 registers. When 1 is written to this bit, the LCNT00 value is set to LCNT01 to LCNT15. This bit automatically returns to 0 after the writing of 1. This bit is read as 0.

LCINTC Bit (Frequency-Divided LOCO Clock Rise Interrupt Enable)

This bit enables or disables an interrupt request generated by the rising edge of the frequency-divided LOCO clock. The interrupt request is generated as a LOCOI interrupt request.

LCINTD Bit (LOCO Count Value Deviation Exceedance Interrupt Enable)

This bit enables or disables an interrupt request generated by the deviation exceedance of the LOCO count value. The interrupt request is generated as a LOCOI interrupt request.

LCINTO Bit (LCNT Overflow Interrupt Enable)

This bit enables or disables an interrupt request generated by an overflow of the LCNT counter. The interrupt request is generated as a LOCOI interrupt request.

LCTO[2:0] Bits (Frequency-Divided LOCO Clock Rise Interrupt Skipping Count Setting)

These bits set the skipping count for the frequency-divided LOCO clock rise interrupt.

LCNTAT Bit (LOCO Count Result Skipping Setting)

This bit specifies whether to skip the transfers of the LOCO count results to LCNTn (n = 00 to 15) as many times as the count specified with LCTO[2:0] bits.

TPSC[1:0] Bits (LOCO Count Clock Select)

These bits select the clock for counting frequency-divided LOCO clock (LCNT operation clock).

LPSC[1:0] Bits (Frequency-Divided LOCO Clock Select)

These bits select the frequency division ratio of the frequency-divided LOCO clock.
To set LPSC[1:0] to a value other than 00, IWDT.IWDTCR.CKS[3:0] should be a value other than 00xx.

18.2.12 LOCO Count Status Register (LCST)

Address: 000C 2082h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	—	—	—	—	—	LISO	LISD	LISC
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	LISC	Frequency-Divided LOCO Clock Rise Interrupt Request Flag	0: No interrupt request is generated. 1: An interrupt request is generated.	R/(W)*1
b1	LISD	LOCO Count Value Deviation Exceedance Interrupt Request Flag	0: No interrupt request is generated. 1: An interrupt request is generated.	R/(W)*1
b2	LISO	LCNT Overflow Interrupt Request Flag	0: No interrupt request is generated. 1: An interrupt request is generated.	R/(W)*1
b15 to b3	—	Reserved	These bits are read as 0. The write value should be 0.	R/W

Note 1. Only 0 can be written to clear the flag.

LCST indicates the count status of the frequency-divided LOCO clock.

LISC Flag (Frequency-Divided LOCO Clock Rise Interrupt Request Flag)

This bit is a flag for an interrupt request generated at the rising edge of the frequency-divided LOCO clock. The next interrupt due to the frequency-divided LOCO clock rising edge will not occur until this flag is cleared.
[Setting condition]
The frequency-divided LOCO clock has a rising edge with LCINTC in LCCR set to 1.
[Clearing condition]
0 is written to this bit.

LISD Flag (LOCO Count Value Deviation Exceedance Interrupt Request Flag)

This bit is a flag for an interrupt request generated by LOCO count value deviation exceedance. The next interrupt due to the LOCO count value deviation exceedance will not occur until this flag is cleared.
[Setting condition]
The LOCO count value deviation exceedance has occurred with LCCR.LCINTD set to 1.
[Clearing condition]
0 is written to this bit.

LISO Flag (LCNT Overflow Interrupt Flag)

This bit is a flag for an interrupt request generated by the LCNT counter overflow. The next interrupt due to the LCNT counter overflow will not occur until this flag is cleared.
[Setting condition]
An overflow of the LCNT counter has occurred with LCCR.LCINTO set to 1.
[Clearing condition]
0 is written to this bit.

18.2.13 LOCO Count Value Register (LCNT)

Address: 000C 2084h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

The LCNT counter counts the frequency-divided LOCO clock. The LCNT counter can only be read from.

18.2.14 LOCO Count Result Average Register (LCNTA)

Address: 000C 2086h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

LCNTA indicates the average of the frequency-divided LOCO clock counting results (LCNT00 to LCNT15). LCNTA can only be read from.

18.2.15 LOCO Count Result Register n (LCNTn) (n = 00 to 15)

Address: LCNT00 000C 2088h, LCNT01 000C 208Ah, LCNT02 000C 208Ch, LCNT03 000C 208Eh, LCNT04 000C 2090h, LCNT05 000C 2092h, LCNT06 000C 2094h, LCNT07 000C 2096h, LCNT08 000C 2098h, LCNT09 000C 209Ah, LCNT10 000C 209Ch, LCNT11 000C 209Eh, LCNT12 000C 20A0h, LCNT13 000C 20A2h, LCNT14 000C 20A4h, LCNT15 000C 20A6h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

LCNTn indicates the result of counting the frequency-divided LOCO clock. This register can be modified only when counting is stopped (LCCR.LCNTE bit = 0).
The count value in LCNT00 is the latest result.

18.2.16 LOCO Count Upper/Lower Permissible Deviation Register (LCNTDU, LCNTDL)

Address: LCNTDU 000C 20A8h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Address: LCNTDL 000C 20AAh

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

LCNTDU and LCNTDL set the permissible deviation for the value obtained by counting the frequency-divided LOCO clock cycles.

The LOCO count value deviation exceedance interrupt is generated when the LCNT00 value exceeds the upper limit (LCNTA + LCNTDU) of the deviation or falls below the lower limit (LCNTA − LCNTDL) of the deviation.

18.2.17 General PWM Timer I/O Control Register (GTIOR)

Address: GPT0.GTIOR 000C 2100h, GPT1.GTIOR 000C 2180h, GPT2.GTIOR 000C 2200h, GPT3.GTIOR 000C 2280h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	OBHLD	OBDFLT	GTIOB[5: 0]						OAHLD	OADFLT	GTIOA[5: 0]					
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b5 to b0	GTIOA[5: 0]	GTIOCnA Pin Function Select	See Table 18.5.	R/W
b6	OADFLT	Output Value at GTIOCnA Pin Count Stop	0: The GTIOCnA pin outputs low when counting is stopped. 1: The GTIOCnA pin outputs high when counting is stopped.	R/W
b7	OAHLD	Output Retain at GTIOCnA Pin Count Start/ Stop	0: The GTIOCnA pin output level at start/stop of counting depends on the register setting. 1: The GTIOCnA pin output level is retained at start/ stop of counting.	R/W
b13 to b8	GTIOB[5: 0]	GTIOCnB Pin Function Select	See Table 18.5.	R/W
b14	OBDFLT	Output Value at GTIOCnB Pin Count Stop	0: The GTIOCnB pin outputs low when counting is stopped. 1: The GTIOCnB pin outputs high when counting is stopped.	R/W
b15	OBHLD	Output Retain at GTIOCnB Pin Count Start/ Stop	0: The GTIOCnB pin output level at start/stop of counting depends on the register setting. 1: The GTIOCnB pin output level is retained at start/ stop of counting.	R/W

GPTn.GTIOR sets the functions of the GTIOCnA and GTIOCnB pins (n = 0 to 3). Each channel has one GTIOCnA pin and one GTIOCnB pin.

GTIOA[5:0] Bits (GTIOCnA Pin Function Select)

These bits select the GTIOCnA pin function. For details, see Table 18.5.

OADFLT Bit (Output Value at GTIOCnA Pin Count Stop)

This bit sets whether the GTIOCnA pin outputs high or low when counting is stopped.

OAHLD Bit (Output Retain at GTIOCnA Pin Count Start/Stop)

This bit specifies whether the GTIOCnA pin output level is retained or the level depends on the register setting when counting is started or stopped.

[When the OAHLD bit is set to 0]

- The value specified by bit 4 in GTIOR is output when counting starts.
- The value specified by the OADFLT bit is output when counting stops.
- If the OADFLT bit is modified while counting is stopped, it is immediately reflected in the output.

[When the OAHLD bit is set to 1]

- The output is retained when counting starts or stops.

GTIOB[5:0] Bits (GTIOCnB Pin Function Select)

These bits select the GTIOCnB pin function. For details, see Table 18.5.

OBDFLT Bit (Output Value at GTIOCnB Pin Count Stop)

This bit sets whether the GTIOCnB pin outputs high or low when counting is stopped.

OBHLD Bit (Output Retain at GTIOCnB Pin Count Start/Stop)

This bit specifies whether the GTIOCnB pin output level is retained or the level depends on the register setting when counting is started or stopped.

[When the OBHLD bit is set to 0]

- The value specified by bit 4 in GTIOR is output when counting starts.
- The value specified by the OBDFLT bit is output when counting stops.
- If the OBDFLT bit is modified while counting is stopped, it is immediately reflected in the output.

[When the OBHLD bit is set to 1]

- The output is retained when counting starts or stops.

Table 18.5 Settings of GTIOA[5:0] Bits (GTIOB[5:0] Bits) (1 / 2)

GTIOA/GTIOB[5:0] Bits						Function			
b5	b4	b3	b2	b1	b0	b5	b4	b3, b2	b1, b0
0	0	0	0	0	0	Compare match	Initial output is Low.	Output retained at cycle end	Output retained at GPTn.GTCCRA/ GTCCRB compare match
0	0	0	0	0	1				Low output at GPTn.GTCCRA/ GTCCRB compare match
0	0	0	0	1	0				High output at GPTn.GTCCRA/ GTCCRB compare match
0	0	0	0	1	1				Toggle output at GPTn.GTCCRA/ GTCCRB compare match
0	0	0	1	0	0			Low output at cycle end	Output retained at GPTn.GTCCRA/ GTCCRB compare match
0	0	0	1	0	1				Low output at GPTn.GTCCRA/ GTCCRB compare match
0	0	0	1	1	0				High output at GPTn.GTCCRA/ GTCCRB compare match
0	0	0	1	1	1				Toggle output at GPTn.GTCCRA/ GTCCRB compare match
0	0	1	0	0	0			High output at cycle end	Output retained at GPTn.GTCCRA/ GTCCRB compare match
0	0	1	0	0	1				Low output at GPTn.GTCCRA/ GTCCRB compare match
0	0	1	0	1	0				High output at GPTn.GTCCRA/ GTCCRB compare match
0	0	1	0	1	1				Toggle output at GPTn.GTCCRA/ GTCCRB compare match
0	0	1	1	0	0			Toggle output at cycle end	Output retained at GPTn.GTCCRA/ GTCCRB compare match
0	0	1	1	0	1				Low output at GPTn.GTCCRA/ GTCCRB compare match
0	0	1	1	1	0				High output at GPTn.GTCCRA/ GTCCRB compare match
0	0	1	1	1	1				Toggle output at GPTn.GTCCRA/ GTCCRB compare match

Table 18.5 Settings of GTIOA[5:0] Bits (GTIOB[5:0] Bits) (2 / 2)

GTIOA/GTIOB[5:0] Bits						Function			
b5	**b4**	**b3**	**b2**	**b1**	**b0**	**b5**	**b4**	**b3, b2**	**b1, b0**
0	1	0	0	0	0	Compare match	Initial output is High.	Output retained at cycle end	Output retained at GPTn.GTCCRA/ GTCCRB compare match
0	1	0	0	0	1				Low output at GPTn.GTCCRA/ GTCCRB compare match
0	1	0	0	1	0				High output at GPTn.GTCCRA/ GTCCRB compare match
0	1	0	0	1	1				Toggle output at GPTn.GTCCRA/ GTCCRB compare match
0	1	0	1	0	0			Low output at cycle end	Output retained at GTPn.GTCCRA/ GTCCRB compare match
0	1	0	1	0	1				Low output at GTPn.GTCCRA/ GTCCRB compare match
0	1	0	1	1	0				High output at GPTn.GTCCRA/ GTCCRB compare match
0	1	0	1	1	1				Toggle output at GPTn.GTCCRA/ GTCCRB compare match
0	1	1	0	0	0			High output at cycle end	Output retained at GTPn.GTCCRA/ GTCCRB compare match
0	1	1	0	0	1				Low output at GPTn.GTCCRA/ GTCCRB compare match
0	1	1	0	1	0				High output at GPTn.GTCCRA/ GTCCRB compare match
0	1	1	0	1	1				Toggle output at GPTn.GTCCRA/ GTCCRB compare match
0	1	1	1	0	0			Toggle output at cycle end	Output retained at GTPn.GTCCRA/ GTCCRB compare match
0	1	1	1	0	1				Low output at GPTn.GTCCRA/ GTCCRB compare match
0	1	1	1	1	0				High output at GPTn.GTCCRA/ GTCCRB compare match
0	1	1	1	1	1				Toggle output at GPTn.GTCCRA/ GTCCRB compare match
1	x	x	x	0	0	Input capture	Don't care		Input capture at rising edge
1	x	x	x	0	1				Input capture at falling edge
1	x	x	x	1	0				Input capture at both edges
1	x	x	x	1	1				

x: Don't care

Note 1. The cycle end is an overflow (GTCNT = GTPR in up-count operation) or underflow (GTCNT = 0 in down-count operation) for saw waves, and the trough (GTCNT = 0) for triangle waves.

Note 2. When the timing of a cycle end and the timing of a GTCCRA/GTCCRB compare match are the same in a compare-match operation, the b3-b2 setting is given priority in saw-wave PWM mode, and the b1-b0 setting is given priority in any other mode.

Note 3. Even though a compare match is set in GTIOR, output will not be made to the pins. GTONCR needs to be set separately.

18.2.18 General PWM Timer Interrupt Output Setting Register (GTINTAD)

Address: GPT0.GTINTAD 000C 2102h, GPT1.GTINTAD 000C 2182h, GPT2.GTINTAD 000C 2202h, GPT3.GTINTAD 000C 2282h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	ADTRBDEN	ADTRBUEN	ADTRADEN	ADTRAUEN	EINT	—	—	—	GTINTPR[1:0]		GTINTF	GTINTE	GTINTD	GTINTC	GTINTB	GTINTA
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	GTINTA	GTCCRA Compare Match/Input Capture Interrupt Enable	0: Interrupt request is disabled. 1: Interrupt request is enabled.	R/W
b1	GTINTB	GTCCRB Compare Match/Input Capture Interrupt Enable	0: Interrupt request is disabled. 1: Interrupt request is enabled.	R/W
b2	GTINTC	GTCCRC Compare Match Interrupt Enable	0: Interrupt request is disabled. 1: Interrupt request is enabled.	R/W
b3	GTINTD	GTCCRD Compare Match Interrupt Enable	0: Interrupt request is disabled. 1: Interrupt request is enabled.	R/W
b4	GTINTE	GTCCRE Compare Match Interrupt Enable	0: Interrupt request is disabled. 1: Interrupt request is enabled.	R/W
b5	GTINTF	GTCCRF Compare Match Interrupt Enable	0: Interrupt request is disabled. 1: Interrupt request is enabled.	R/W
b7, b6	GTINTPR[1:0]	GTPR Compare Match Interrupt Enable	b7 b6 0 0: Interrupt request is disabled. 0 1: In saw-wave mode, interrupt requests are enabled at overflows. In triangle-wave mode, interrupt requests are enabled at crests. 1 0: In saw-wave mode, interrupt requests are enabled at underflows. In triangle-wave mode, interrupt requests are enabled at troughs. 1 1: In saw-wave mode, interrupt requests are enabled at both overflows and underflows. In triangle-wave mode, interrupt requests are enabled at both crests and troughs.	R/W
b10 to b8	—	Reserved	These bits are read as 0. The write value should be 0.	R/W
b11	EINT	Dead Time Error Interrupt Enable	0: Interrupt request is disabled. 1: Interrupt request is enabled.	R/W
b12	ADTRAUEN	GTADTRA Compare Match (Up-Counting) A/D Converter Start Request Enable	0: A/D converter start request is disabled. 1: A/D converter start request is enabled.	R/W
b13	ADTRADEN	GTADTRA Compare Match(Down-Counting) A/D Converter Start Request Enable	0: A/D converter start request is disabled. 1: A/D converter start request is enabled.	R/W
b14	ADTRBUEN	GTADTRB Compare Match (Up-Counting) A/D Converter Start Request Enable	0: A/D converter start request is disabled. 1: A/D converter start request is enabled.	R/W
b15	ADTRBDEN	GTADTRB Compare Match(Down-Counting) A/D Converter Start Request Enable	0: A/D converter start request is disabled. 1: A/D converter start request is enabled.	R/W

GTINTAD enables or disables interrupt requests and A/D converter start requests.

GTINTA Bit (GTCCRA Compare Match/Input Capture Interrupt Enable)

This bit enables or disables interrupt requests by GTCCRA compare match/input capture (GTCIA).

GTINTB Bit (GTCCRB Compare Match/Input Capture Interrupt Enable)

This bit enables or disables interrupt requests by GTCCRB compare match/input capture (GTCIB).

GTINTC Bit (GTCCRC Compare Match Interrupt Enable)

This bit enables or disables interrupt requests by GTCCRC compare match (GTCIC).

GTINTD Bit (GTCCRD Compare Match Interrupt Enable)

This bit enables or disables interrupt requests by GTCCRD compare match (GTCID). The interrupt request is generated as a GTCIC interrupt.

GTINTE Bit (GTCCRE Compare Match Interrupt Enable)

This bit enables or disables interrupt requests by GTCCRE compare match (GTCIE).

GTINTF Bit (GTCCRF Compare Match Interrupt Enable)

This bit enables or disables interrupt requests by GTCCRF compare match (GTCIF). The interrupt request is generated as a GTCIE interrupt.

GTINTPR[1:0] Bits (GTPR Compare Match Interrupt Request Setting)

These bits enable or disable interrupt requests by a GTPR compare match (GTCNT counter overflow) and those by a GTCNT counter underflow (GTCIV).

EINT Bit (Dead Time Error Interrupt Enable)

This bit enables or disables interrupt requests by a dead time error (GTCIC). The interrupt request is generated as a GTCIC interrupt.

ADTRAUEN Bit (GTADTRA Compare Match (Up-Count Operation) A/D Converter Start Request Enable)

This bit enables or disables A/D converter start requests generated by GTADTRA compare matches during GTCNT up-count operation.

ADTRADEN Bit (GTADTRA Compare Match (Down-Count Operation) A/D Converter Start Request Enable)

This bit enables or disables A/D converter start requests generated by GTADTRA compare matches during GTCNT down-count operation.

ADTRBUEN Bit (GTADTRB Compare Match (Up-Count Operation) A/D Converter Start Request Enable)

This bit enables or disables A/D converter start requests generated by GTADTRB compare matches during GTCNT up-count operation.

ADTRBDEN Bit (GTADTRB Compare Match (Down-Count Operation) A/D Converter Start Request Enable)

This bit enables or disables A/D converter start requests generated by GTADTRB compare matches during GTCNT down-count operation.

18.2.19 General PWM Timer Control Register (GTCR)

Address: GPT0.GTCR 000C 2104h, GPT1.GTCR 000C 2184h, GPT2.GTCR 000C 2204h, GPT3.GTCR 000C 2284h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	CCLR[1:0]		—	—	TPCS[1:0]		—	—	—	—	—	MD[2:0]		
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b2 to b0	MD[2:0]	Mode Select	b2 b0 0 0 0: Saw-wave PWM mode (single buffer or double buffer possible) 0 0 1: Saw-wave one-shot pulse mode (fixed buffer operation) 0 1 0: Setting prohibited 0 1 1: Setting prohibited 1 0 0: Triangle-wave PWM mode 1 (16-bit transfer at crest) (single buffer or double buffer possible) 1 0 1: Triangle-wave PWM mode 2 (16-bit transfer at crest and trough) (single buffer or double buffer possible) 1 1 0: Triangle-wave PWM mode 3 (32-bit transfer at trough) fixed buffer operation) 1 1 1: Setting prohibited	R/W
b7 to b3	—	Reserved	These bits are read as 0. The write value should be 0.	R/W
b9, b8	TPCS[1:0]	Timer Prescaler Select	b9 b8 0 0: ICLK (system clock) 0 1: ICLK/2 (system clock/2) 1 0: ICLK/4 (system clock/4) 1 1: ICLK/8 (system clock/8)	R/W
b11, b10	—	Reserved	These bits are read as 0. The write value should be 0.	R/W
b13, b12	CCLR[1:0]	Counter Clear Source Select	b13 b12 0 0: None of the following clearing sources is specified. 0 1: Cleared by GTCCRA input capture 1 0: Cleared by GTCCRB input capture 1 1: Cleared by counter clearing in another channel performing synchronized clearing/synchronized operation	R/W
b15, b14	—	Reserved	These bits are read as 0. The write value should be 0.	R/W

GTCR controls GTCNT.
GTCR should be set while GTCNT operation is stopped.

MD[2:0] Bits (Mode Select)

These bits select the GPT operating mode.

TPCS[1:0] Bits (Timer Prescaler Select)

These bits select the clock for GTCNT. A clock source can be selected independently for each channel.

CCLR[1:0] Bits (Counter Clear)

These bits select the clearing source for GTCNT.

In saw-wave mode, when synchronized clearing is selected, synchronized clearing is handled equally to clearing by the counter's overflow or underflow and the pin output and buffer transfer are performed. However, the overflow flag and underflow flag are not set.

In triangle-wave mode, when synchronized clearing is selected, only counter clearing is performed. Though the counter value becomes 0, it is not handled as a trough.

Once 01b, 10b, or 11b is selected as a counter clear source, counter clearing by the source is executed whether the GPTn.GTCNT count operation is performed (GTSTR.CTSn = 1; n = 0 to 3) or stopped (GTSTR.CSTn = 0, n = 0 to 3).

18.2.20 General PWM Timer Buffer Enable Register (GTBER)

Address: GPT0.GTBER 000C 2106h, GPT1.GTBER 000C 2186h, GPT2.GTBER 000C 2206h, GPT3.GTBER 000C 2286h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	ADTDB	ADTTB[1:0]		—	ADTDA	ADTTA[1:0]		—	CCRSWT	PR[1:0]		CCRB[1:0]		CCRA[1:0]	
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1, b0	CCRA[1:0]	GTCCRA Buffer Operation	b1 b0 0 0: Buffer operation is not performed 0 1: Single buffer operation (GTCCRA ⇔ GTCCRC) 1 x: Double buffer operation (GTCCRA ⇔ GTCCRC ⇔ GTCCRD)	R/W
b3, b2	CCRB[1:0]	GTCCRB Buffer Operation	b3 b2 0 0: Buffer operation is not performed 0 1: Single buffer operation (GTCCRB ⇔ GTCCRE) 1 x: Double buffer operation (GTCCRB ⇔ GTCCRE ⇔ GTCCRF)	R/W
b5, b4	PR[1:0]	GTPR Buffer Operation	b5 b4 0 0: Buffer operation is not performed 0 1: Single buffer operation (GTPBR ⇒ GTPR) 1 x: Double buffer operation (GTPDBR ⇒ GTPBR ⇒ GTPR)	R/W
b6	CCRSWT	GTCCRA and GTCCRB Forcible Buffer Operation	Writing 1 to this bit forcibly performs buffer transfer of GTCCRA and GTCCRB. This bit automatically returns to 0 after the writing of 1. This bit is read as 0.	R/W
b7	—	Reserved	This bit is read as 0. The write value should be 0.	R/W
b9, b8	ADTTA[1:0]	GTADTRA Buffer Transfer Timing Select	• Triangle waves b9 b8 0 0: No transfer 0 1: Transfer at crest 1 0: Transfer at trough 1 1: Transfer at both crest and trough • Saw waves b9 b8 0 0: No transfer Values other than 0 0: Transfer at underflow (during down-counting) or overflow (during up-counting) is performed.	R/W
b10	ADTDA	GTADTRA Double Buffer Operation	0: Single buffer operation (GTADTBRA → GTADTRA) 1: Double buffer operation (GTADTDBRA → GTADTBRA → GTADTDRA)	R/W
b11	—	Reserved	This bit is read as 0. The write value should be 0.	R/W
b13, b12	ADTTB[1:0]	GTADTRB Buffer Transfer Timing Select	• Triangle waves b13 b12 0 0: No transfer 0 1: Transfer at crest 1 0: Transfer at trough 1 1: Transfer at both crest and trough • Saw waves b13 b12 0 0: No transfer Values other than 0 0: Transfer at an underflow (in down-counting) or overflow (in up-counting) is performed.	R/W
b14	ADTDB	GTADTRB Double Buffer Operation	0: Single buffer operation (GTADTBRB → GTADTRB) 1: Double buffer operation (GTADTDBRB → GTADTBRB → GTADTDRB)	R/W
b15	—	Reserved	This bit is read as 0. The write value should be 0.	R/W

GTBER makes settings for buffer operation.
GTBER should be set while GTCNT operation is stopped.

CCRA[1:0] Bits (GTCCRA Buffer Operation)

These bits set buffer operation with GTCCRA, GTCCRC, and GTCCRD combined. When buffer operation is restricted by the operating mode set in GTCR, the GTCR setting is given priority.*

CCRB[1:0] Bits (GTCCRB Buffer Operation)

These bits set buffer operation with GTCCRB, GTCCRE, and GTCCRF combined. When buffer operation is restricted by the operating mode set in GTCR, the GTCR setting is given priority.*

PR[1:0] Bits (GTPR Buffer Operation)

These bits set buffer operation with GTPR, GTPBR, and GTPDBR combined.

CCRSWT Bit (GTCCRA and GTCCRB Forcible Buffer Operation)

Writing 1 to the CCRSWT bit forcibly performs buffer transfer of GTCCRA and GTCCRB. This bit automatically returns to 0 after the writing of 1. This bit is read as 0.
This bit is valid only when counting is stopped with compare match operation specified.

ADTTA[1:0] Bits (GTADTRA Buffer Transfer Timing Select)

These bits set the transfer timing for buffer operation of GTADTRA, GTADTBRA, and GTADTDBRA.

ADTDA Bit (GTADTRA Double Buffer Operation)

These bits set buffer operation with GTADTRA, GTADTBRA, and GTADTDBRA combined.

ADTTB[1:0] Bits (GTADTRB Buffer Transfer Timing Select)

These bits set the transfer timing for buffer operation of GTADTRB, GTADTBRB, and GTADTDBRB.

ADTDB Bit (GTADTRB Double Buffer Operation)

These bits set buffer operation with GTADTRB, GTADTBRB, and GTADTDBRB combined.

Note: • The buffer operation mode is fixed in saw-wave one-shot pulse mode or triangle-wave PWM mode 3 (32-bit transfer at trough).

18.2.21 General PWM Timer Count Direction Register (GTUDC)

Address: GPT0.GTUDC 000C 2108h, GPT1.GTUDC 000C 2188h, GPT2.GTUDC 000C 2208h, GPT3.GTUDC 000C 2288h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	UDF	UD
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Bit	Symbol	Bit Name	Description	R/W
b0	UD	Count Direction Setting	0: GTCNT counts down. 1: GTCNT counts up.	R/W
b1	UDF	Forcible Count Direction Setting	0: Not forcibly set 1: Forcibly set	R/W
b15 to b2	—	Reserved	These bits are read as 0. The write value should be 0.	R/W

GTUDC sets the direction in which GTCNT counts (up-counting or down-counting).

- In saw-wave mode

When the UD value is set to 0 during up-counting, the count direction is changed at an overflow (GTCNT = GTPR).
When the UD value is set to 1 during up-counting, the count direction is changed at an underflow (GTCNT = 0).
If the UD value is changed from 1 to 0 with the UDF bit being 0 and while counting is stopped, the counter starts up-count operation and the count direction is changed at an overflow (GTCNT = GTPR).
If the UD value is changed from 0 to 1 with the UDF bit being 0 and while counting is stopped, the counter starts down-count operation and the count direction is changed at an underflow (GTCNT = 0).
When the UDF bit is set to 1 while counting is stopped, the UD bit value at that time is reflected in the count direction when counting starts.

- In triangle-wave mode

Even if the UD value is changed during counting, the change will not be reflected in the count direction.
If the UD value is modified while the UDF bit is 0 and counting is stopped, the change will not be reflected in the count direction when counting starts. If the UDF bit is set to 1 while counting is stopped, the UD bit value at that time is reflected in the count direction when counting starts.

UD Bit (Count Direction Setting)

This bit sets the count direction (up-counting or down-counting) for GTCNT.

UDF Bit (Forcible Count Direction Setting)

This bit forcibly sets the count direction when GTCNT starts operation as the UD value.
Only 0 should be written to this bit during counter operation.
When 1 has been written to this bit while counting is stopped, this bit should be returned to 0 before counting starts.

18.2.22 General PWM Timer Interrupt and A/D Converter Start Request Skipping Setting Register (GTITC)

Address: GPT0.GTITC 000C 210Ah, GPT1.GTITC 000C 218Ah, GPT2.GTITC 000C 220Ah, GPT3.GTITC 000C 228Ah

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	ADTBL	—	ADTAL	—	IVTT[2:0]			IVTC[1:0]		ITLF	ITLE	ITLD	ITLC	ITLB	ITLA
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	ITLA	GTCCRA Compare Match/ Input Capture Interrupt Link	0: Not linked with GTCIV interrupt skipping function. 1: Linked with GTCIV interrupt skipping function.	R/W
b1	ITLB	GTCCRB Compare Match/ Input Capture Interrupt Link	0: Not linked with GTCIV interrupt skipping function. 1: Linked with GTCIV interrupt skipping function.	R/W
b2	ITLC	GTCCRC Compare Match Interrupt Link	0: Not linked with GTCIV interrupt skipping function. 1: Linked with GTCIV interrupt skipping function.	R/W
b3	ITLD	GTCCRD Compare Match Interrupt Link	0: Not linked with GTCIV interrupt skipping function. 1: Linked with GTCIV interrupt skipping function.	R/W
b4	ITLE	GTCCRE Compare Match Interrupt Link	0: Not linked with GTCIV interrupt skipping function. 1: Linked with GTCIV interrupt skipping function.	R/W
b5	ITLF	GTCCRF Compare Match Interrupt Link	0: Not linked with GTCIV interrupt skipping function. 1: Linked with GTCIV interrupt skipping function.	R/W
b7, b6	IVTC[1:0]	GTCIV Interrupt Skipping Function Select	b7 b6 0 0: Skipping is not performed 0 1: Overflow for saw waves and crest for triangle waves are counted and skipped 1 0: Underflow for saw waves and trough for triangle waves are counted and skipped 1 1: Both overflow and underflow for saw waves and both crest and trough for triangle waves are counted and skipped	R/W
b10 to b8	IVTT[2:0]	GTCIV Interrupt Skipping Count Select	b10 b8 0 0 0: Skipping is not performed 0 0 1: Skipping count of 1 0 1 0: Skipping count of 2 0 1 1: Skipping count of 3 1 0 0: Skipping count of 4 1 0 1: Skipping count of 5 1 1 0: Skipping count of 6 1 1 1: Skipping count of 7	R/W
b11	—	Reserved	This bit is read as 0. The write value should be 0.	R/W
b12	ADTAL	GTADTRA A/D Converter Start Request Link	0: Not linked with GTCIV interrupt skipping function. 1: Linked with GTCIV interrupt skipping function.	R/W
b13	—	Reserved	This bit is read as 0. The write value should be 0.	R/W
b14	ADTBL	GTADTRB A/D Converter Start Request Link	0: Not linked with GTCIV interrupt skipping function. 1: Linked with GTCIV interrupt skipping function.	R/W
b15	—	Reserved	This bit is read as 0. The write value should be 0.	R/W

GTITC sets the skipping function for GTCNT counter overflows (GTPR compare match) or underflow interrupts (GTCIV) and also sets whether to link the other interrupts and A/D converter start requests with the GTCIV interrupt skipping function. Note that dead time error interrupts cannot be linked with the GTCIV interrupt skipping function. When the interrupt skipping function is set, the change in the corresponding status flag is also skipped

ITLA Bit (GTCCRA Compare Match/Input Capture Interrupt Link)

This bit specifies whether to link the GTCCRA compare match/input capture interrupt (GTCIA) with the GTCIV interrupt skipping function.

ITLB Bit (GTCCRB Compare Match/Input Capture Interrupt Link)

This bit specifies whether to link the GTCCRB compare match/input capture interrupt (GTCIB) with the GTCIV interrupt skipping function.

ITLC Bit (GTCCRC Compare Match Interrupt Link)

This bit specifies whether to link the GTCCRC compare match interrupt (GTCIC) with the GTCIV interrupt skipping function.

ITLD Bit (GTCCRD Compare Match Interrupt Link)

This bit specifies whether to link the GTCCRD compare match interrupt (GTCID) with the GTCIV interrupt skipping function.

ITLE Bit (GTCCRE Compare Match Interrupt Link)

This bit specifies whether to link the GTCCRE compare match interrupt (GTCIE) with the GTCIV interrupt skipping function.

ITLF Bit (GTCCRF Compare Match Interrupt Link)

This bit specifies whether to link the GTCCRF compare match interrupt (GTCIF) with the GTCIV interrupt skipping function.

IVTC[1:0] Bits (GTCIV Interrupt Skipping Function Select)

These bits set the skipping function for the GTPR compare match (GTCNT overflow)/GTCNT underflow interrupt (GTCIV).

IVTT[2:0] Bits (GTCIV Interrupt Skipping Count Select)

These bits select the skipping count for the GTPR compare match (GTCNT overflow)/GTCNT underflow interrupt (GTCIV).

When modifying the IVTT[2:0] bits, first set the IVTC[1:0] bits to 00b.

ADTAL Bit (GTADTRA A/D Converter Start Request Link)

This bit specifies whether to link the GTADTRA A/D converter start request with GTCIVn interrupt skipping function.

ADTBL Bit (GTADTRB A/D Converter Start Request Link)

This bit specifies whether to link the GTADTRB A/D converter start request with GTCIVn interrupt skipping function.

18.2.23 General PWM Timer Status Register (GTST)

Address: GPT0.GTST 000C 210Ch, GPT1.GTST 000C 218Ch, GPT2.GTST 000C 220Ch, GPT3.GTST 000C 228Ch

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	TUCF	—	—	—	DTEF	ITCNT[2:0]			TCFPU	TCFPO	TCFF	TCFE	TCFD	TCFC	TCFB	TCFA
Value after reset:	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	TCFA	Input Capture/Compare Match Flag A	0: No GTCCRA input capture/compare match has occurred. 1: A GTCCRA input capture/compare match has occurred.	R/(W)*1
b1	TCFB	Input Capture/Compare Match Flag B	0: No GTCCRB input capture/compare match has occurred. 1: A GTCCRB input capture/compare match has occurred.	R/(W)*1
b2	TCFC	Compare Match Flag C	0: No GTCCRC compare match has occurred. 1: A GTCCRC compare match has occurred.	R/(W)*1
b3	TCFD	Compare Match Flag D	0: No GTCCRD compare match has occurred. 1: A GTCCRD compare match has occurred.	R/(W)*1
b4	TCFE	Compare Match Flag E	0: No GTCCRE compare match has occurred. 1: A GTCCRE compare match has occurred.	R/(W)*1
b5	TCFF	Compare Match Flag F	0: No GTCCRF compare match has occurred. 1: A GTCCRF compare match has occurred.	R/(W)*1
b6	TCFPO	Overflow Flag	0: No overflow or crest has occurred. 1: An overflow or crest has occurred.	R/(W)*1
b7	TCFPO	Underflow Flag	0: No underflow or trough has occurred. 1: An underflow or trough has occurred.	R/(W)*1
b10 to b8	ITCNT[2:0]	GTCIV Interrupt Skipping Count Counter	Counter for counting the number of times a timer interrupt has been skipped.	R
b11	DTEF	Dead Time Error Flag	0: No dead time error has occurred. 1: A dead time error has occurred.	R
b14 to b12	—	Reserved	These bits are read as 0. The write value should be 0.	R/W
b15	TUCF	Count Direction Flag	0: The GPTn.GTCNT counter counts downward. 1: The GPTn.GTCNT counter counts upward.	R

Note 1. Only 0 can be written to clear the flag.

GTST indicates the status of the GPT.

TCFA Flag (Input Capture/Compare Match Flag A)

This status flag indicates generation of a GTCCRA input capture/compare match.

[Setting conditions]

- GTCNT matches GTCCRA when GTCCRA functions as a compare match register.
- The GTCNT value is transferred to GTCCRA by an input capture signal when GTCCRA functions as an input capture register.

[Clearing conditions]

- 0 is written to the TCFA flag.

TCFB Flag (Input Capture/Compare Match Flag B)

This status flag indicates generation of a GTCCRB input capture/compare match.

[Setting conditions]

- GTCNT matches GTCCRB when GTCCRB functions as a compare match register
- The GTCNT value is transferred to GTCCRB by an input capture signal if GTCCRB is functioning as an input capture register

[Clearing conditions]

- 0 is written to the TCFB flag.

TCFC Flag (Compare Match Flag C)

This status flag indicates generation of a GTCCRC compare match.
Comparison is not performed when GTCCRC is used for buffer operation.

[Setting condition]

- GTCNT matches GTCCRC.

[Clearing conditions]

- 0 is written to the TCFC flag.

[Conditions for not performing comparison]

- GTCR.MD[2:0] = 001b (saw-wave one-shot pulse mode)
- GTCR.MD[2:0] = 110b (triangle-wave PWM mode 3)
- GTBER.CCRA[1:0] = 01b, 10b, or 11b (GTCCRC is used for buffer operation)

TCFD Flag (Compare Match Flag D)

This status flag indicates generation of a GTCCRD compare match.
Comparison is not performed when GTCCRD is used for buffer operation.

[Setting condition]

- GTCNT matches GTCCRD.

[Clearing conditions]

0 is written to the TCFD flag.

[Conditions for not performing comparison]

- GTCR.MD[2:0] = 001b (saw-wave one-shot pulse mode)
- GTCR.MD[2:0] = 110b (triangle-wave PWM mode 3)
- GTBER.CCRA[1:0] = 10b or 11b (GTCCRD is used for buffer operation)

TCFE Flag (Compare Match Flag E)

This status flag indicates generation of a GTCCRE compare match.
Comparison is not performed when GTCCRE is used for buffer operation.

[Setting condition]

- GTCNT matches GTCCRE.

[Clearing conditions]

- 0 is written to the TCFE flag.

[Conditions for not performing comparison]

- GTCR.MD[2:0] = 001b (saw-wave one-shot pulse mode)
- GTCR.MD[2:0] = 110b (triangle-wave PWM mode 3)
- GTBER.CCRB[1:0] = 01b, 10b, or 11b (GTCCRE is used for buffer operation)

TCFF Flag (Compare Match Flag F)

This status flag indicates generation of a GTCCRF compare match.
Comparison is not performed when GTCCRF is used for buffer operation.

[Setting condition]

- GTCNT matches GTCCRF.

[Clearing conditions]

- 0 is written to the TCFF flag.

[Conditions for not performing comparison]

- GTCR.MD[2:0] = 001b (saw-wave one-shot pulse mode)
- GTCR.MD[2:0] = 110b (triangle-wave PWM mode 3)
- GTBER.CCRB[1:0] = 10b or 11b (GTCCRF is used for buffer operation)

TCFPO Flag (Overflow Flag)

This flag indicates generation of an overflow or crest.

[Setting conditions]

- For saw waves, when an overflow has occurred (GTCNT matches GTPR during up-count operation).
- For triangle waves, when a crest has occurred (GTCNT matches GTPR).

[Clearing conditions]

- 0 is written to the TCFPO flag.

TCFPU Flag (Underflow Flag)

- This flag indicates generation of an underflow or trough.

[Setting conditions]

- For saw waves, when an underflow has occurred (GTCNT reaches 0 during down-count operation).
- For triangle waves, when a trough has occurred (GTCNT reaches 0).

[Clearing conditions]

- 0 is written to the TCFPU flag.

ITCNT[2:0] Bits (GTCIV Interrupt Skipping Count Counter)

When the GTCIV interrupt skipping function is used (the GTITC.IVTC[1:0] bits are set to a value other than 00b), the counter is incremented by 1 every time the GTCIV interrupt source is generated.

[Clearing conditions]

- The GTCIV interrupt skipping function is not used (GTITC.IVTT[2:0] is 000b when GTITC.IVTC[1:0] is 00b).
- The GTCIV interrupt skipping count matches the specified count (ITCNT[2:0] matches the skipping count specified by GTITC.IVTT[2:0]).

DTEF Flag (Dead Time Error Flag)

This flag indicates that the timer output toggle point after the automatic addition of dead time has exceeded the timer cycle.
This flag returns to 0 when the timer output toggle point after the automatic addition of dead time is back within the cycle. This flag can only be read from. (Writing 0 to clear the flag is not allowed.)
When an interrupt by the DTEF flag is enabled (GTINTAD.EINT = 1), a GTCIC interrupt is generated every time the DTEF flag changes from 0 to 1.
[Setting condition]

- The timer output toggle point after the automatic addition of dead time has exceeded the timer cycle.

[Clearing condition]

- The timer output toggle point after the automatic addition of dead time is within the timer cycle.

TUCF Flag (Count Direction Flag)

This flag indicates the count direction of GTCNT.

18.2.24 General PWM Timer Counter (GTCNT)

Address: GPT0.GTCNT 000C 210Eh, GPT1.GTCNT 000C 218Eh, GPT2.GTCNT 000C 220Eh, GPT3.GTCNT 000C 228Eh

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

GTCNT is a 16-bit readable/writable counter. There is a total of four GTCNT counters, one counter for each channel. GTCNT can be written to only when counting is stopped; GTCNT cannot be written to during counting operation. GTCNT should always be accessed in 16-bits. Access in 8-bit units is prohibited.

18.2.25 General PWM Timer Compare Capture Register m (GTCCRm) (m = A to F)

Address: GPT0.GTCCRA 000C 2110h, GPT1.GTCCRA 000C 2190h, GPT2.GTCCRA 000C 2210h, GPT3.GTCCRA 000C 2290h,
GPT0.GTCCRB 000C 2112h, GPT1.GTCCRB 000C 2192h, GPT2.GTCCRB 000C 2212h, GPT3.GTCCRB 000C 2292h,
GPT0.GTCCRC 000C 2114h, GPT1.GTCCRC 000C 2194h, GPT2.GTCCRC 000C 2214h, GPT3.GTCCRC 000C 2294h,
GPT0.GTCCRD 000C 2116h, GPT1.GTCCRD 000C 2196h, GPT2.GTCCRD 000C 2216h, GPT3.GTCCRD 000C 2296h,
GPT0.GTCCRE 000C 2118h, GPT1.GTCCRE 000C 2198h, GPT2.GTCCRE 000C 2218h, GPT3.GTCCRE 000C 2298h,
GPT0.GTCCRF 000C 211Ah, GPT1.GTCCRF 000C 219Ah, GPT2.GTCCRF 000C 221Ah, GPT3.GTCCRF 000C 229Ah

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

GTCCRm registers are 16-bit readable/writable registers. There is a total of 24 GTCCRm registers, six registers for each channel.
GTCCRA and GTCCRB are registers used for both output compare and input capture.
GTCCRC and GTCCRE are compare match registers that can also function as buffer registers for GTCCRA and GTCCRB.
GTCCRD and GTCCRF are compare match registers that can also function as buffer registers for GTCCRC and GTCCRE (double-buffer registers for GTCCRA and GTCCRB).

18.2.26 General PWM Timer Cycle Setting Register (GTPR)

Address: GPT0.GTPR 000C 211Ch, GPT1.GTPR 000C 219Ch, GPT2.GTPR 000C 221Ch, GPT3.GTPR 000C 229Ch

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

GTPR is a 16-bit readable/writable register that sets the maximum count value of GTCNT. There is a total of four GTPR registers, one register for each channel.
For saw waves, the value of (GTPR × 1) is the cycle. For triangle waves, the value of (GTPR value × 2) is the cycle.

18.2.27 General PWM Timer Cycle Setting Buffer Register (GTPBR)

Address: GPT0.GTPBR 000C 211Eh, GPT1.GTPBR 000C 219Eh, GPT2.GTPBR 000C 221Eh, GPT3.GTPBR 000C 229Eh

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

GTPBR is a 16-bit readable/writable register that functions as a buffer register for GTPR. There is a total of four GTPPR registers, one register for each channel.

18.2.28 General PWM Timer Cycle Setting Double-Buffer Register (GTPDBR)

Address: GPT0.GTPDBR 000C 2120h, GPT1.GTPDBR 000C 21A0h, GPT2.GTPDBR 000C 2220h, GPT3.GTPDBR 000C 22A0h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

GTPDBR is a 16-bit readable/writable register that functions as a buffer register for GTPBR (double-buffer register for GTPR). There is a total of four GTPDBR registers, one register for each channel.

18.2.29 A/D Converter Start Request Timing Register m (GTADTRm) (m = A, B)

Address: GPT0.GTADTRA 000C 2124h, GPT1.GTADTRA 000C 21A4h, GPT2.GTADTRA 000C 2224h, GPT3.GTADTRA 000C 22A4h, GPT0.GTADTRB 000C 212Ch, GPT1.GTADTRB 000C 21Ach, GPT2.GTADTRB 000C 222Ch, GPT3.GTADTRB 000C 22ACh

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

GTADTRm registers are 16-bit readable/writable registers that set the timing of A/D converter start request generation. When the GTADTRm value matches the GTCNT counter value, an A/D converter start request is generated. There is a total of eight GTPPRm registers, two register for each channel.
GTADTRm should always be accessed in 16-bit units. Access in 8-bit units is prohibited.

18.2.30 A/D Converter Start Request Timing Buffer Register m (GTADTBRm) (m = A, B)

Address: GPT0.GTADTBRA 000C 2126h, GPT1.GTADTBRA 000C 21A6h, GPT2.GTADTBRA 000C 2226h, GPT3.GTADTBRA 000C 22A6h, GPT0.GTADTBRB 000C 212Eh, GPT1.GTADTBRB 000C 21AEh, GPT2.GTADTBRB 000C 222Eh, GPT3.GTADTBRB 000C 22AEh

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

GTADTBRm registers are 16-bit readable/writable registers that function as buffer registers for GTADTRm. There is a total of eight GTPPBRm registers, two register for each channel.
GTADTBRm should always be accessed in 16-bit units. Access in 8-bit units is prohibited.

18.2.31 A/D Converter Start Request Timing Double-Buffer Register m (GTADTDBRm) (m = A, B)

Address: GPT0.GTADTDBRA 000C 2128h, GPT1.GTADTDBRA 000C 21A8h, GPT2.GTADTDBRA 000C 2228h, GPT3.GTADTDBRA 000C 22A8h, GPT0.GTADTDBRB 000C 2130h, GPT1.GTADTDBRB 000C 21B0h, GPT2.GTADTDBRB 000C 2230h, GPT3.GTADTDBRB 000C 22B0h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

GTADTDBRm registers are 16-bit readable/writable registers that function as buffer registers for GTADTBRm (double-buffer registers for GTADTR). There is a total of eight GTPPDBRm registers, two register for each channel. GTADTDBRm should always be accessed in 16-bit units. Access in 8-bit units is prohibited.

18.2.32 General PWM Timer Output Negate Control Register (GTONCR)

Address: GPT0.GTONCR 000C 2134h, GPT1.GTONCR 000C 21B4h, GPT2.GTONCR 000C 2234h, GPT3.GTONCR 000C 22B4h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	OBE	OAE	—	SWN	—	—	—	NFV	NFS[3:0]				NVB	NVA	NEB	NEA
Value after reset:	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	NEA	GTIOCnA Pin Negate Control Enable	0: Negate is disabled 1: Negate is enabled	R/W
b1	NEB	GTIOCnB Pin Negate Control Enable	0: Negate is disabled 1: Negate is enabled	R/W
b2	NVA	GTIOCnA Pin Negate Value Setting	0: GTIOCnA pin is set to 0 when negate control is performed. 1: GTIOCnA pin is set to 1 when negate control is performed.	R/W
b3	NVB	GTIOCnB Pin Negate Value Setting	0: GTIOCnB pin is set to 0 when negate control is performed. 1: GTIOCnB pin is set to 1 when negate control is performed.	R/W
b7 to b4	NFS[3:0]	GTIOC Output Negate Source Select	b7 b4 0 0 0 0: AN000 comparator detection 0 0 0 1: AN001 comparator detection 0 0 1 0: AN002 comparator detection 0 0 1 1: Setting prohibited 0 1 0 0: AN100 comparator detection 0 1 0 1: AN101 comparator detection 0 1 1 0: AN102 comparator detection 0 1 1 1: GTETRG pin input 1 x x x: Software control (control through SWN bit)	R/W
b8	NFV	Negate Source Polarity Select	0: Negate control is provided when the negate source has become 0. 1: Negate control is provided when the negate source has become 1.	R/W
b11 to b9	—	Reserved	These bits are read as 0. The write value should be 0.	R/W
b12	SWN	Software Negate Control	When NFV bit is 0: 0: Negate control is provided. 1: Negate control is not provided. When NFV bit is 1: 0: Negate control is not provided. 1: Negate control is provided.	R/W
b13	—	Reserved	This bit is read as 0. The write value should be 0.	R/W

Bit	Symbol	Bit Name	Description	R/W
b14	OAE	GTIOCnA Pin Output Enable	0: No pin output 1: Pin output	R/W
b15	OBE	GTIOCnB Pin Output Enable	0: No pin output 1: Pin output	R/W

Note 1. Note: n=0 to 3

GTONCR controls negate of the GTIOCnA pin output and GTIOCnB pin output.

NEA Bit (GTIOCnA Pin Negate Control Enable)

This bit enables negate control of the GTIOCnA pin output.

NEB Bit (GTIOCnB Pin Negate Control Enable)

This bit enables negate control of the GTIOCnB pin output.

NVA Bit (GTIOCnA Pin Negate Value Setting)

This bit sets the output value of the GTIOCnA pin at negate control.

NVB Bit (GTIOCnB Pin Negate Value Setting)

This bit sets the output value of the GTIOCnB pin at negate control.

NFS[3:0] Bits (GTIOC Output Negate Source Select)

These bits select the negate source for the GTIOCnA pin output and GTIOCnB pin output.

NFV Bit (Negate Source Polarity Select)

This bit selects the negate source polarity for the GTIOCnA pin output and GTIOCnB pin output.

SWN Bit (Software Negate Control)

This bit specifies whether to provide negate control for the GTIOCnA pin output and GTIOCnB pin output.
This bit setting is valid when software control is selected as the negate source (NFS[3] bit is set to 1).

OAE Bit (GTIOCnA Pin Output Enable)

This bit selects whether to output the GTIOCnA pin output. This bit setting is valid only when compare match has been set (bit 5 in GTIOR is 0).

OBE Bit (GTIOCnB Pin Output Enable)

This bit selects whether to output the GTIOCnB pin output. This bit setting is valid only when compare match has been set (bit 13 in GTIOR is 0).

18.2.33 General PWM Timer Dead Time Control Register (GTDTCR)

Address: GPT0.GTDTCR 000C 2136h, GPT1.GTDTCR 000C 21B6h, GPT2.GTDTCR 000C 2236h, GPT3.GTDTCR 000C 22B6h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	TDFER	—	—	TDBDE	TDBUE	—	—	—	TDE
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	TDE	Negative-Phase Waveform Setting	0: GTCCRB is set without using GTDVU and GTDVD. 1: GTDVU and GTDVD are used to set the compare match value for negative-phase waveform with dead time automatically in GTCCRB.	R/W
b3 to b1	—	Reserved	These bits are read as 0. The write value should be 0.	R/W
b4	TDBUE	GTDVU Buffer Operation Enable	0: GTDVU buffer operation is disabled 1: GTDVU buffer operation is enabled	R/W
b5	TDBDE	GTDVD Buffer Operation Enable	0: GTDVD buffer operation is disabled 1: GTDVD buffer operation is enabled	R/W
b7, b6	—	Reserved	These bits are read as 0. The write value should be 0.	R/W
b8	TDFER	GTDVD Setting	0: GTDVU and GTDVD are set separately. 1: The value written to GTDVU is automatically set to GTDVD.	R/W
b15 to b9	—	Reserved	These bits are read as 0. The write value should be 0.	R/W

GTDTCR enables automatic setting of a compare match value for negative-phase waveform with dead time.

TDE Bit (Negative-Phase Waveform Setting)

This bit sets whether to use GTDVU and GTDVD. When GTDVU and GTDVD are used, the compare match value for a negative-phase waveform with dead time that was obtained by the compare match value of a positive-phase waveform (GTCCRA) and the dead time value (GTDVU and GTDVD) is automatically set in GTCCRB.
The TDE bit setting is ignored in saw-wave PWM mode, and automatic setting does not take place.

The automatically set GTCCRB value has the following upper and lower limit values. If the obtained GTCCRB value is not within the upper or lower limit, the following limit value is set in GTCCRB and the GPTn.GTST.DTEF flag is set to 1.

- Triangle waves
  Upper limit value: GTPR – 1
  Lower limit value: 1 in up-counting, 0 in down-counting
- Saw-wave one-shot pulse mode
  Upper limit value: GTPR
  Lower limit value: 0

TDBUE Bit (GTDVU Buffer Operation Enable)

This bit enables buffer operation with GTDVU and GTDBU combined.
The buffer transfer timing is the trough for triangle waves, and an overflow or underflow for saw waves.

TDBDE Bit (GTDVD Buffer Operation Enable)

This bit enables buffer operation with GTDVD and GTDBD combined.
The buffer transfer timing is the trough for triangle waves, and an overflow or underflow for saw waves.
When this bit and the TDFER bit are set to 1 simultaneously, the TDFER bit setting is given priority.

TDFER Bit (GTDVD Setting)

This bits sets whether or not the value written to GTDVU is also set to GTDVD automatically.

18.2.34 General PWM Timer Dead Time Value Register m (GTDVm) (m = U, D)

Address: GPT0.GTDVU 000C 2138h, GPT1.GTDVU 000C 21B8h, GPT2.GTDVU 000C 2238h, GPT3.GTDVU 000C 22B8h, GPT0.GTDVD 000C 213Ah, GPT1.GTDVD 000C 21Bah, GPT2.GTDVD 000C 223Ah, GPT3.GTDVD 000C 22BAh

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

GTDVm is a 16-bit readable/writable register that sets the dead time for generating PWM waveforms with dead time.
There is a total of eight GTDVm registers, two registers for each channel: GTDVU used for up-counting and GTDVD used for down-counting.
Setting a dead time value that exceeds the cycle is prohibited. The set value can be confirmed by reading from GTCCRB.
When GTDVm is used, writing to GTCCRB is prohibited.
When this register is set to 0, waveforms without dead time are output.
GTDVm should always be accessed in 16-bit units. Access in 8-bit units is prohibited.

18.2.35 General PWM Timer Dead Time Buffer Register m (GTDBm) (m = U, D)

Address: GPT0.GTDBU 000C 213Ch, GPT1.GTDBU 000C 21BCh, GPT2.GTDBU 000C 223Ch, GPT3.GTDBU 000C 22BCh, GPT0.GTDBD 000C 213Eh, GPT1.GTDBD 000C 21Beh, GPT2.GTDBD 000C 223Eh, GPT3.GTDBD 000C 22BEh

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

GTDBm is a 16-bit readable/writable register that functions as a buffer register for GTDVm.
There is a total of eight GTDBm registers, two registers for each channel: GTDBU used for up-counting and GTDBD used for down-counting.

18.2.36 General PWM Timer Output Protection Function Status Register (GTSOS)

Address: GPT0.GTSOS 000C 2140h, GPT1.GTSOS 000C 21C0h, GPT2.GTSOS 000C 2240h, GPT3.GTSOS 000C 22C0h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	SOS[1:0]	
Value after reset:	0	0	0	0	0	0	x	x	0	0	0	0	0	0	0	0

x: Undefined

Bit	Symbol	Bit Name	Description	R/W
b1, b0	SOS[1:0]	Output Protection Function Status	b1 b0 0 0: Normal operation 0 1: Protected state (GTCCRA = 0 is set during transfer at trough or crest) 1 0: Protected state (GTCCRA ≥ GTPR is set during transfer at trough) 1 1: Protected state (GTCCRA ≥ GTPR is set during transfer at crest)	R
b7 to b2	—	Reserved	These bits are read as 0 and cannot be modified.	R
B9, b8	—	Reserved	The read value is undefined. These bits cannot be modified.	R
b15 to b10	—	Reserved	These bits are read as 0 and cannot be modified.	R

GTSOS is a status register that indicates the status of the output protection function. The output protection function is enabled only when the dead time is automatically set (GTDTCR.TDE bit = 1) in triangle-wave mode.

SOS Bit (Output Protection Function Status)

This bit indicates the status of the output protection function in triangle-wave PWM mode. For details of the output protection function, see Output Protection Function for GTIOC Pin Output, Output Protection Function for GTIOC Pin Output Function for GTIOC Pin Output.

18.2.37 General PWM Timer Output Protection Function Temporary Release Register (GTSOTR)

Address: GPT0.GTSOS 000C 2140h, GPT1.GTSOS 000C 21C0h, GPT2.GTSOS 000C 2240h, GPT3.GTSOS 000C 22C0h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	SOTR
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	SOTR	Output Protection Function Temporary Release	0: Protected state is not released 1: Protected state is released	R/W
b15 to b1	—	Reserved	These bits are read as 0. The write value should be 0.	R/W

GTSOTR temporarily releases the protected state of GTIOCnB pin output when output protection has been set.
The protected state can be released only for the case of GTSOS.SOS[1:0] bits = 10b (protected state in which GTCCRA ≥ GTPR has occurred during transfer at trough). The protected state cannot be released for any other case.

SOTR Bit (Output Protection Function Temporary Release)

This bit sets whether to temporarily release the protected state of the GTIOCnB pin output in an output protected state. After the SOTR bit has been set to 1, the output protection function is canceled from the first trough. After the SOTR bit has been set to 0, output protection is resumed from the first trough.

18.3 Operation

18.3.1 Basic Operation

Each channel has a 16-bit timer which performs up-counting, down-counting, and up-/down-counting.
The cycle is controlled by compare register GTPR.
When the counter value matches the value in GTCCRA or GTCCRB, the output from the corresponding pin GTIOCnA or GTIOCnB can be changed (n = 0 to 3). GTCCRA or GTCCRB can be used as an input capture register with the GTIOCnA or GTIOCnB pin as the input.
GTCCRC and GTCCRD can function as buffer registers of GTCCRA, and GTCCRE and GTCCRF can function as buffer registers of GTCCRB.

18.3.1.1 Counter Operation

(1) Periodic Count Operation (in Up-Count Operation)

The counter in each channel starts up-count operation when the corresponding CST bit in GTSTR is set to 1. When the GTCNT value matches the GTPR value (overflow), the GTST.TCFPO flag is set to 1. If the GTINTAD.GTINTPR[0] bit is 1 at this time, a GTCIV interrupt is requested. After GTCNT overflows, up-count operation is resumed from 0000h.
Figure 18.2 shows an example of periodic count operation in up-count operation.

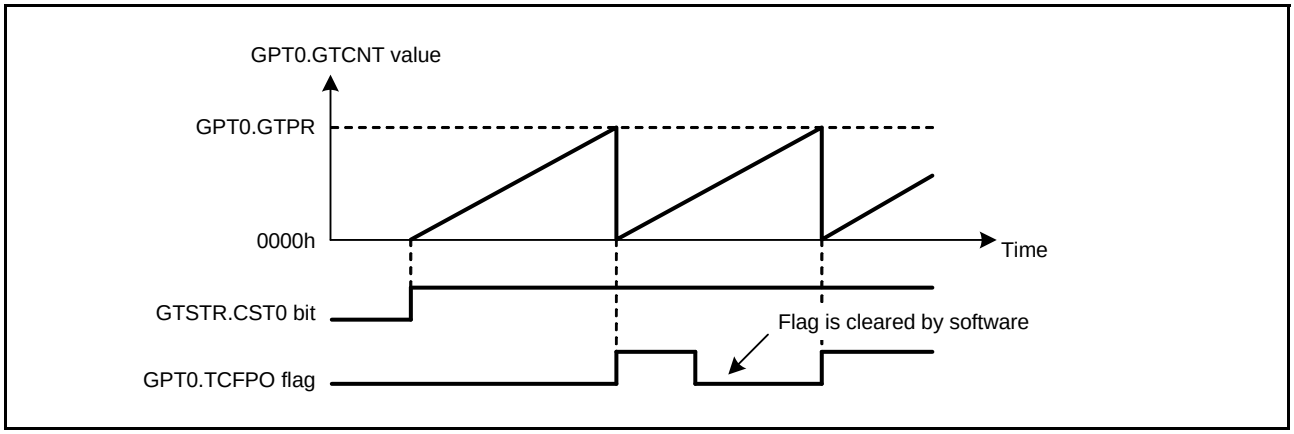


Figure 18.2 Example of Periodic Count Operation (in Up-Count Operation)

Figure 18.3 shows an example for setting periodic count operation in up-count operation.

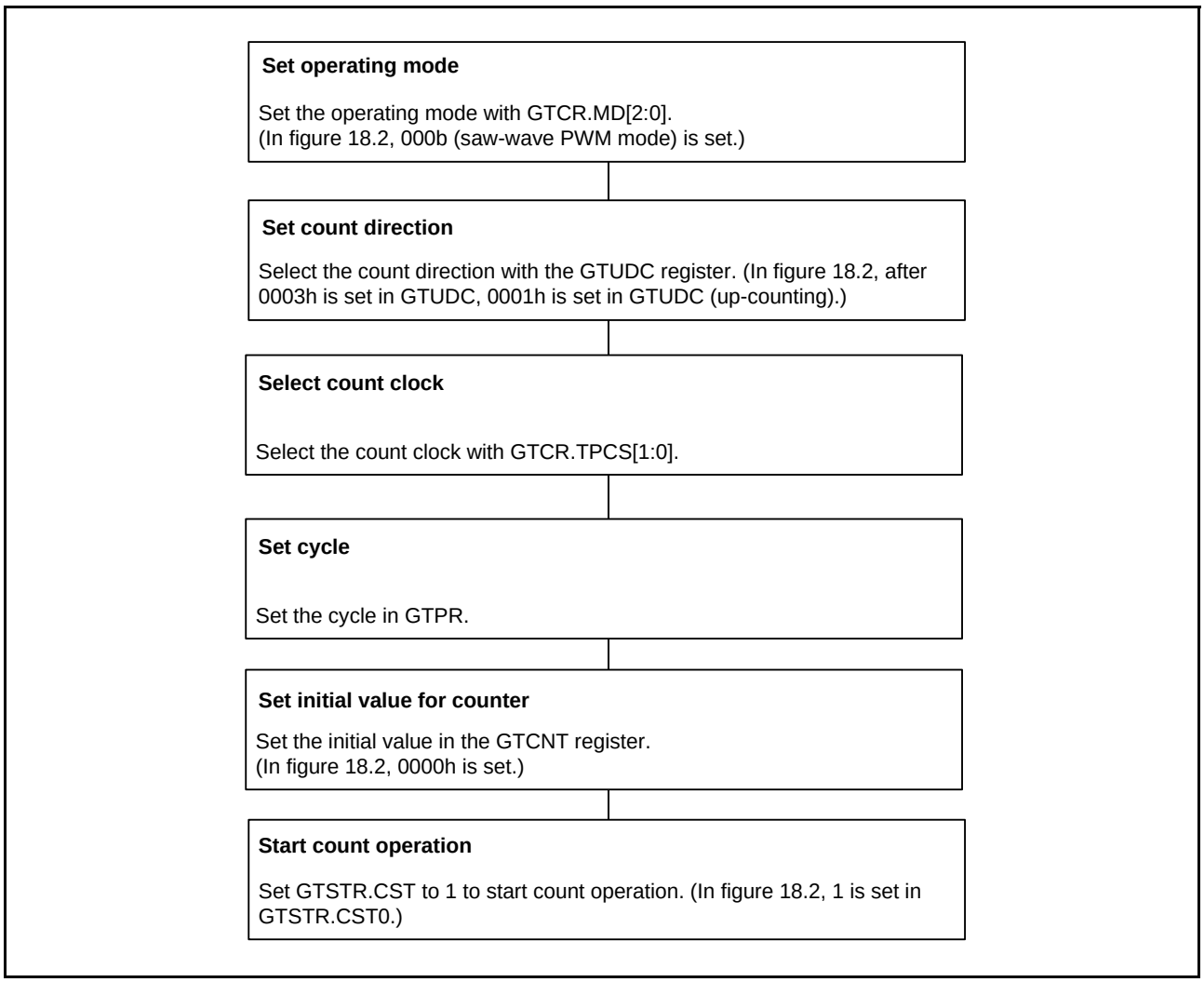


Figure 18.3 Example for Setting Periodic Count Operation (in Up-Count Operation)

(2) Periodic Count Operation (in Down-Count Operation)

The counter in each channel can perform down-count operation by setting GTUDC.
When GTCNT reaches 0 (underflow), the GTST.TCFPU flag is set to 1. If the GTINTAD.GTINTPR[1] bit is 1 at this time, a GTCIV interrupt is requested. After the GTCNT counter underflows, down-count operation is resumed from the GTPR value.
Figure 18.4 shows an example of periodic count operation in down-count operation.

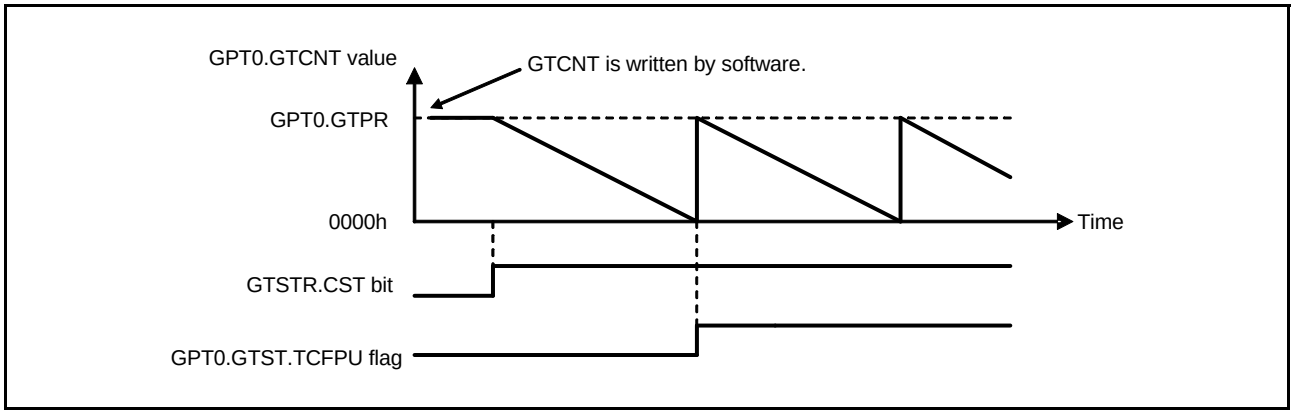


Figure 18.4 Example of Periodic Count Operation (in Down-Count Operation)

Figure 18.5 shows an example for setting periodic count operation in down-count operation.

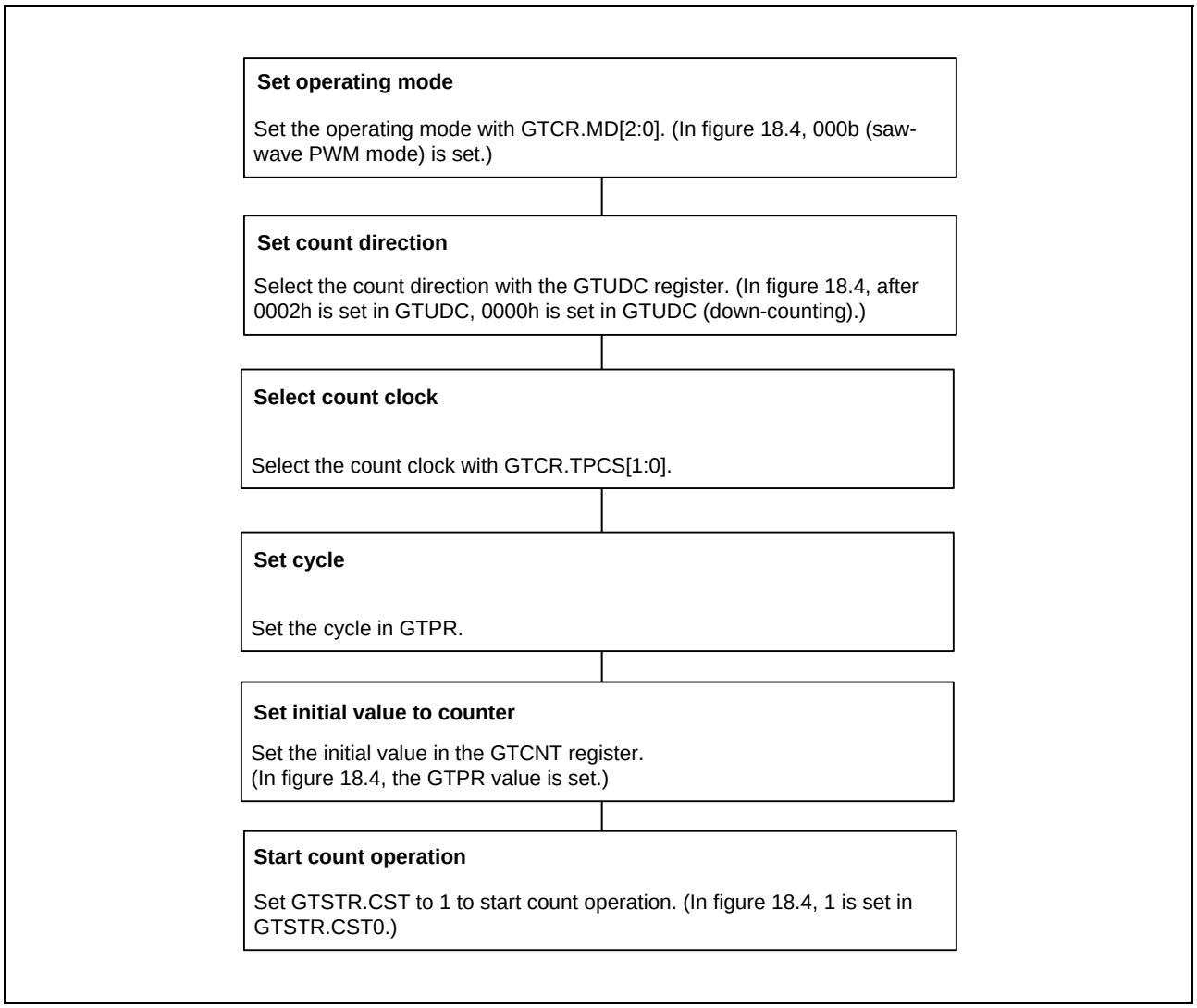


Figure 18.5 Example for Setting Periodic Count Operation (in Down-Count Operation)

18.3.1.2 Waveform Output by Compare Match

When the GPTn.GTCNT counter value matches GTPn.GTCCRA or GTPn.GTCCRB, the GPT can output low or high or toggles output from the corresponding GTIOCnA or GTIOCnB output pin (n = channel number).
In addition, the GTIOCnA or GTIOCnB pin output can be low, high, or toggled at the "cycle end" which is determined by GPTn.GTPR.
The cycle end is:

- For saw waves in up-count operation: When GPTn.GTPR = GPTn.GTCNT (overflow)
- For saw waves in down-count operation: When GPTn.GTPR = 0 (underflow)
- For triangle waves: When GPTn.GTPR = 0 (trough)

(1) Low Output and High Output

Figure 18.6 shows an example of low output and high output operation by a compare match of GTCCRA and GTCCRB.
In this example, up-count operation is performed in GPT0, and settings have been made so that high is output from the GTIOC0A pin by a GPT0.GTCCRA compare match, and low is output from the GTIOC0B pin by a GPT0n.GTCCRB compare match. The pin level does not change when the specified level and pin level match.

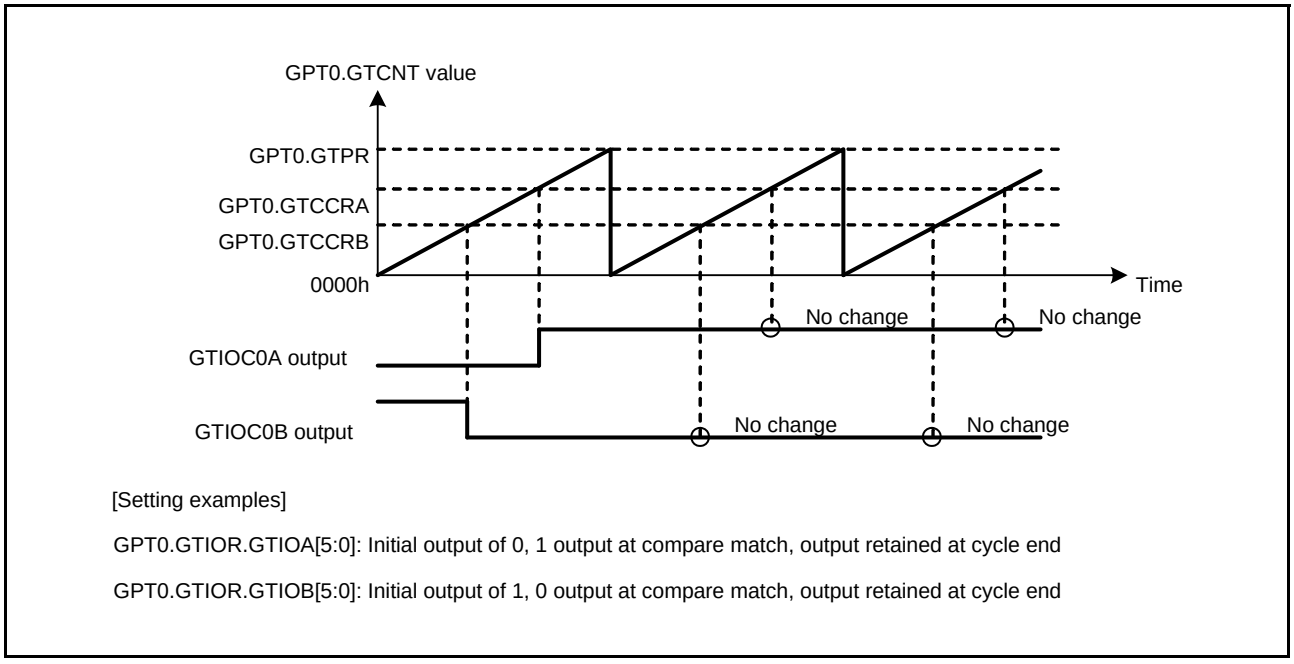


Figure 18.6 Example of Low Output and High Output Operation

Figure 18.7 shows an example for setting low output and high output operation

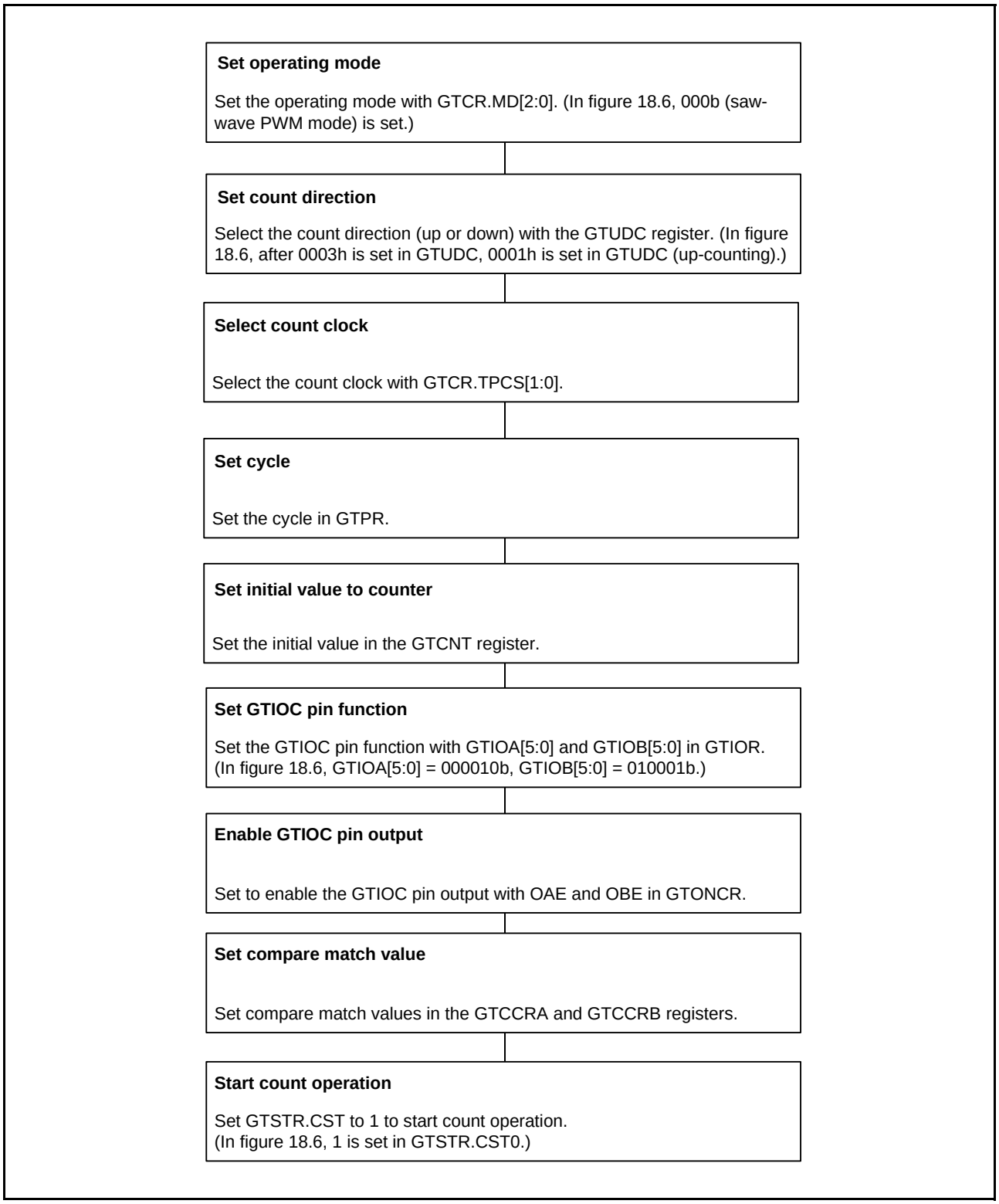
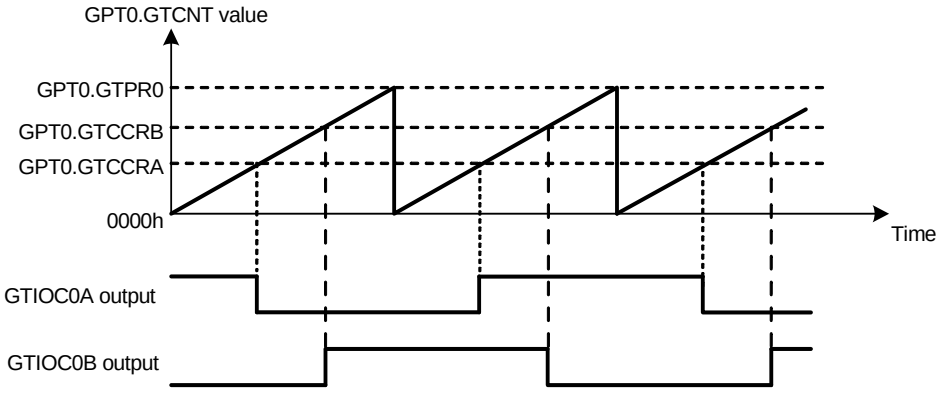


Figure 18.7 Example for Setting Low Output and High Output Operation

(2) Toggled Output

Figure 18.9 and Figure 18.10 show examples of toggled output operation by compare matches of GTCCRA and GTCCRB. In Figure 18.8, up-count operation is performed in GPT0, and settings have been made so that the GTIOC0A pin output by a GPT0.GTCCRA compare match and GTIOC0B pin output by a GPT0n.GTCCRB compare match are toggled.

In Figure 18.9, up-count operation is performed in GPT0, and settings have been made so that the GTIOC0A output is toggled by a compare match of GPT0.GTCCRA and the GTIOC0B output is toggled at the cycle end.

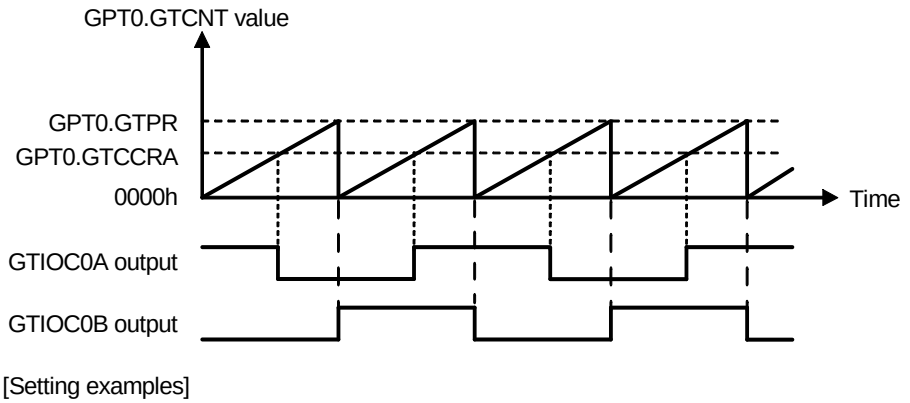


[Setting examples]

GPT0.GTIOR.GTIOA[5:0]: Initial output of 1, toggle output at compare match, output retained at cycle end

GPT0.GTIOR.GTIOB[5:0]: Initial output of 0, toggle output at compare match, output retained at cycle end

Figure 18.8 Example of Toggled Output Operation (1)



[Setting examples]

GPT0.GTIOR.GTIOA[5:0]: Initial output of 1, toggle output at compare match, output retained at cycle end

GPT0.GTIOR.GTIOB[5:0]: Initial output of 0, output retained at compare match, toggle output at cycle end

Figure 18.9 Example of Toggled Output Operation (2)

Figure 18.10 shows an example for setting toggled output operation

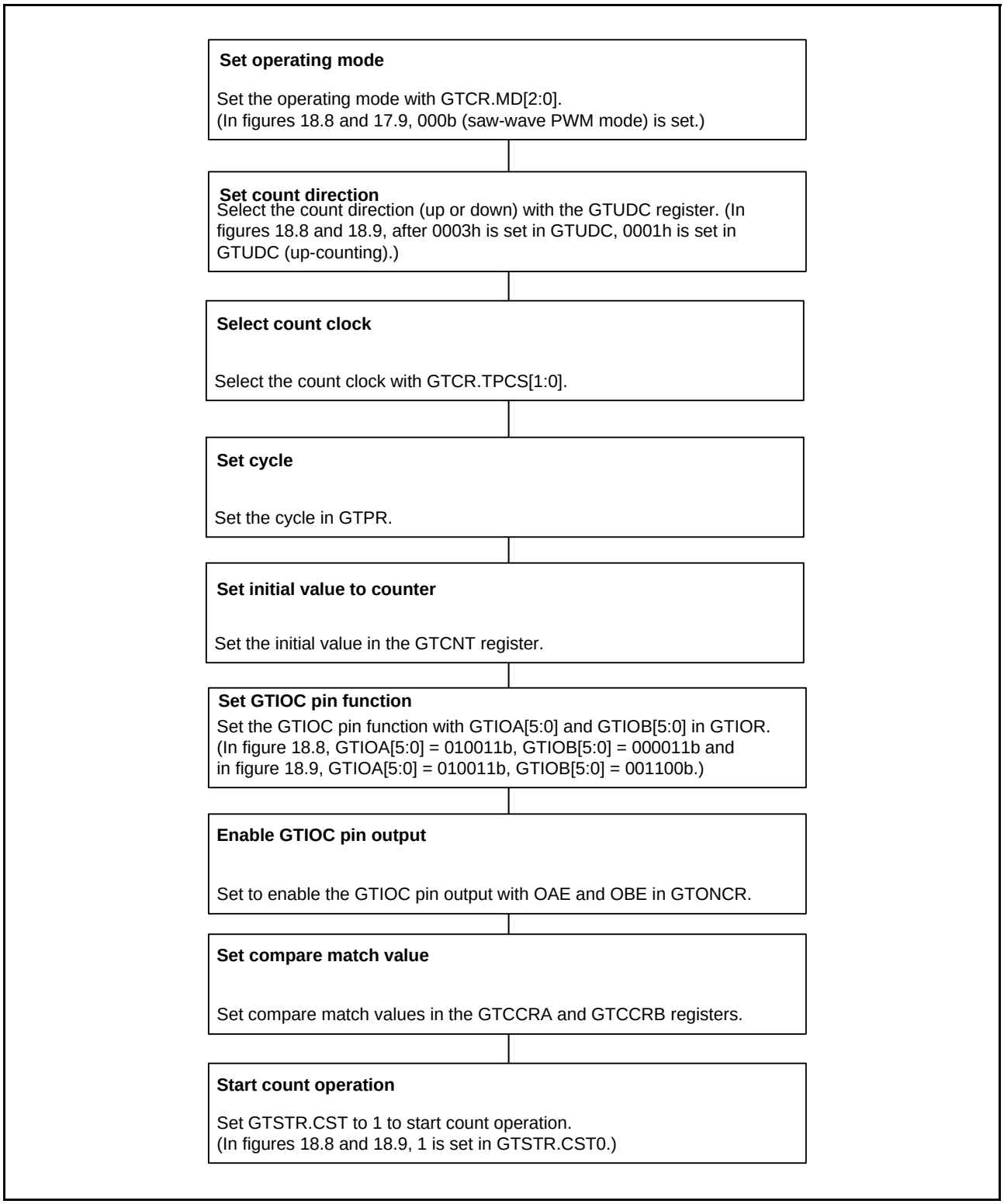


Figure 18.10 Example for Setting Toggled Output Operation

18.3.1.3 Input Capture Function

The GPTn.GTCNT counter value can be transferred to either GPTn.GTCCRA or GPTn.GTCCRB on detection of the input edge of the GTIOCnA input pin or GTIOCnB input pin, respectively (n: channel number). The rising edge, falling edge, or both edges can be selected as the detection edge.

Figure 18.11 shows an example of the input capture function. In this example, up-count operation is performed on GPT0, and settings have been made so that an input capture is performed at both edges of the GTIOC0A input pin and at the rising edge of the GTIOC0B input pin.

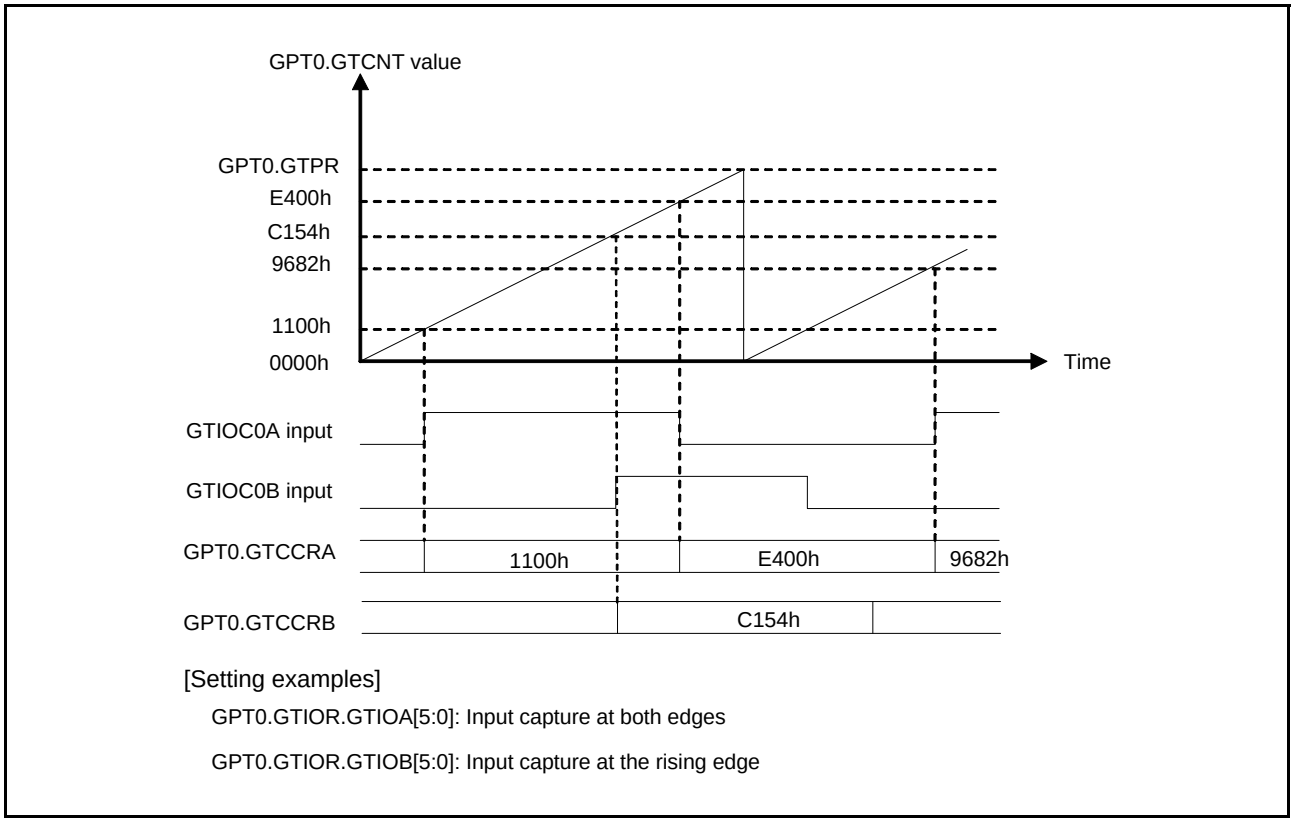


Figure 18.11 Example of Input Capture Operation

Figure 18.12 shows an example for setting input capture operation.

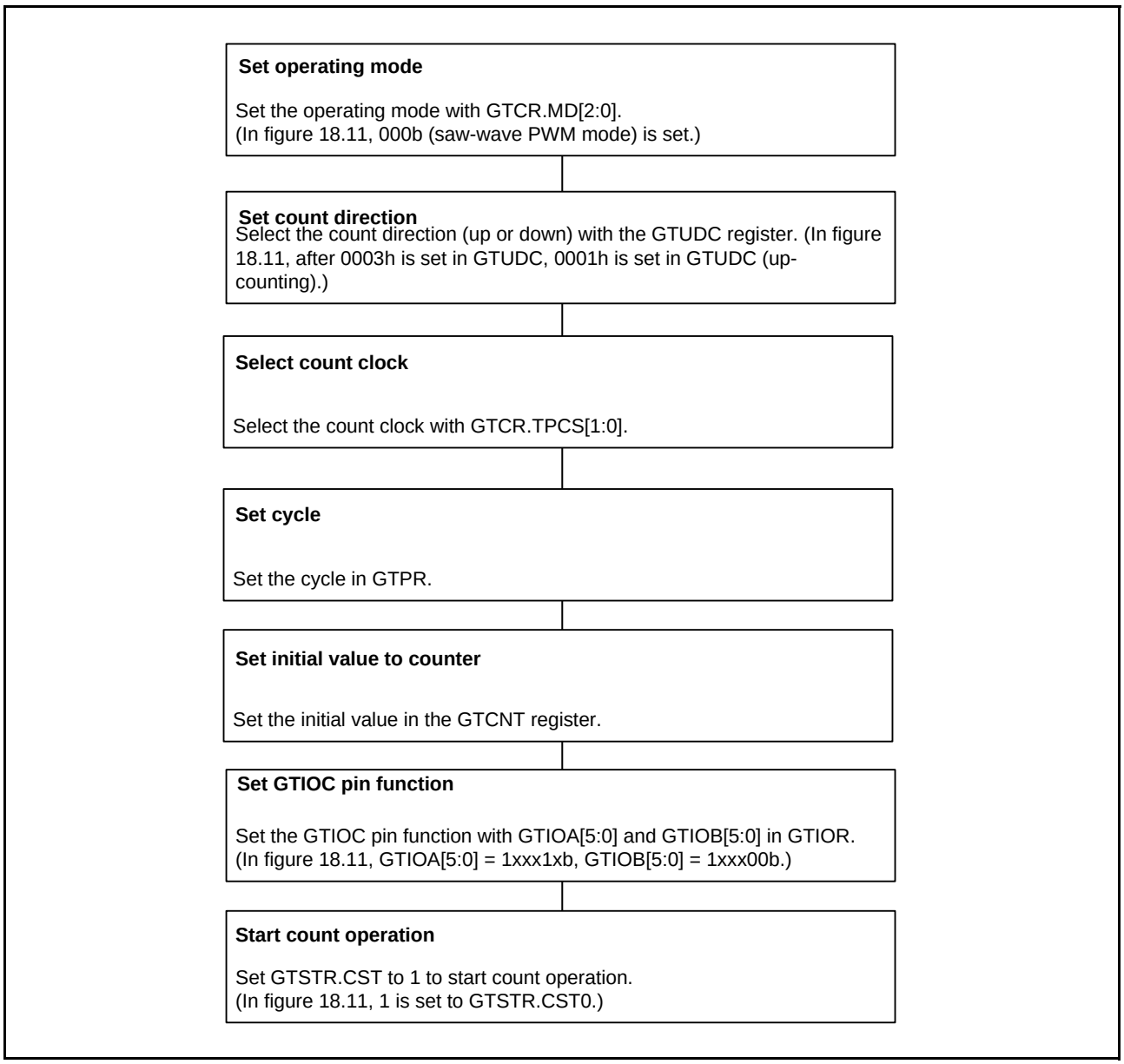


Figure 18.12 Example for Setting Input Capture Operation

18.3.2 Buffer Operation

The following buffer operation can be set with GTBER.

- Buffer operation with GTCCRA, GTCCRC, and GTCCRD used together
- Buffer operation with GTCCRB, GTCCRE, and GTCCRF used together
- Buffer operation with GTPR, GTPBR, and GTPDBR used together
- Buffer operation with GTADTRA, GTADTBRA, and GTADTDBRA used together
- Buffer operation with GTADTRB, GTADTBRB, and GTADTDBRB used together

The following buffer operation can be set with GTDTCR.

- Buffer operation with GTDVU and GTDBU used together
- Buffer operation with GTDVU and GTDBD used together

18.3.2.1 GTPR Register Buffer Operation

GTPBR can function as a buffer register for GTPR, and GTPCBR can function as a buffer register for GTPBR (double-buffer register for GTPR).

The buffer transfer is performed at an overflow (during up-count operation) or an underflow (during down-count operation) in saw-wave mode, and at a trough in triangle-wave mode.

To set GTPR to function as double buffer, set GTBER.PR[1:0] to 10b or 11b. For single buffer operation, set 01b. Not to function as buffer, set 00b.

Figure 18.13 to Figure 18.15 show examples of GTPR buffer operation and Figure 18.16 shows an example for setting GTPR buffer operation.

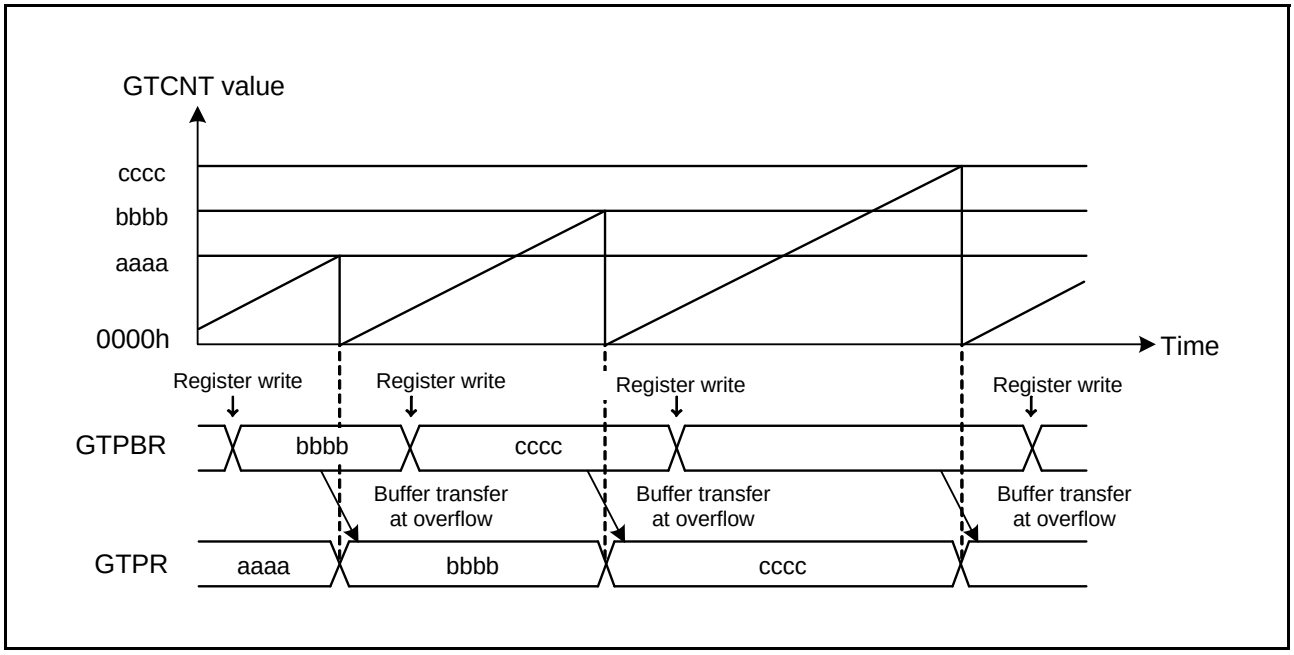


Figure 18.13 Example of GTPR Buffer Operation (Saw Waves in Up-Count Operation)

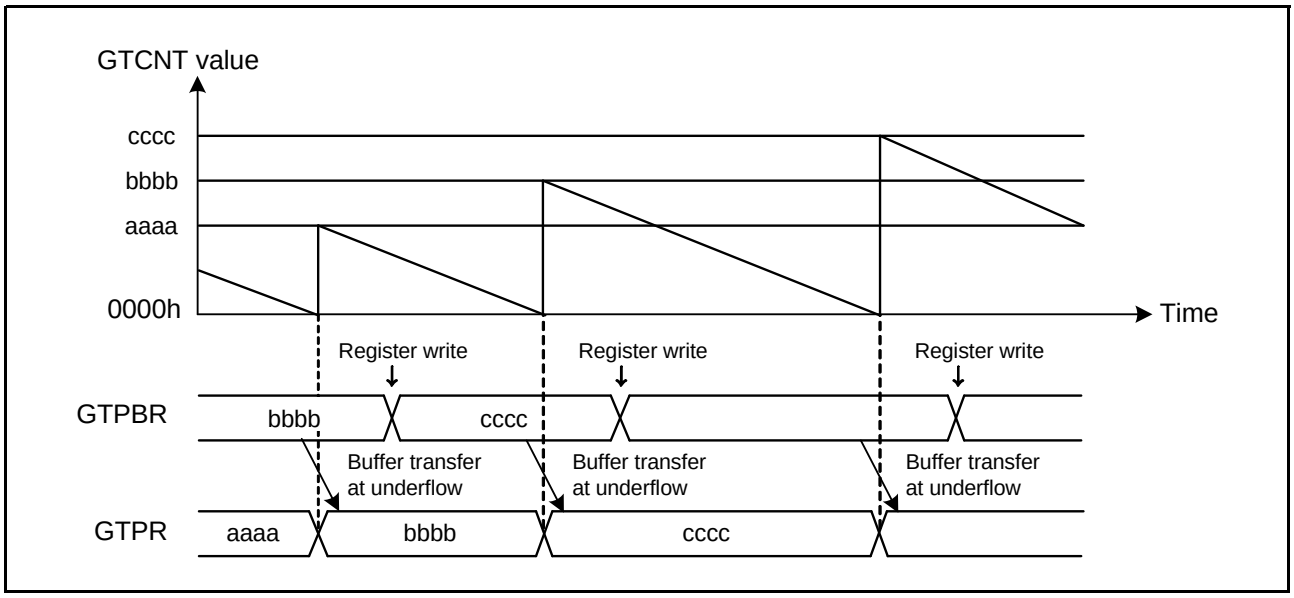


Figure 18.14 Example of GTPR Buffer Operation (Saw Waves in Down-Count Operation)

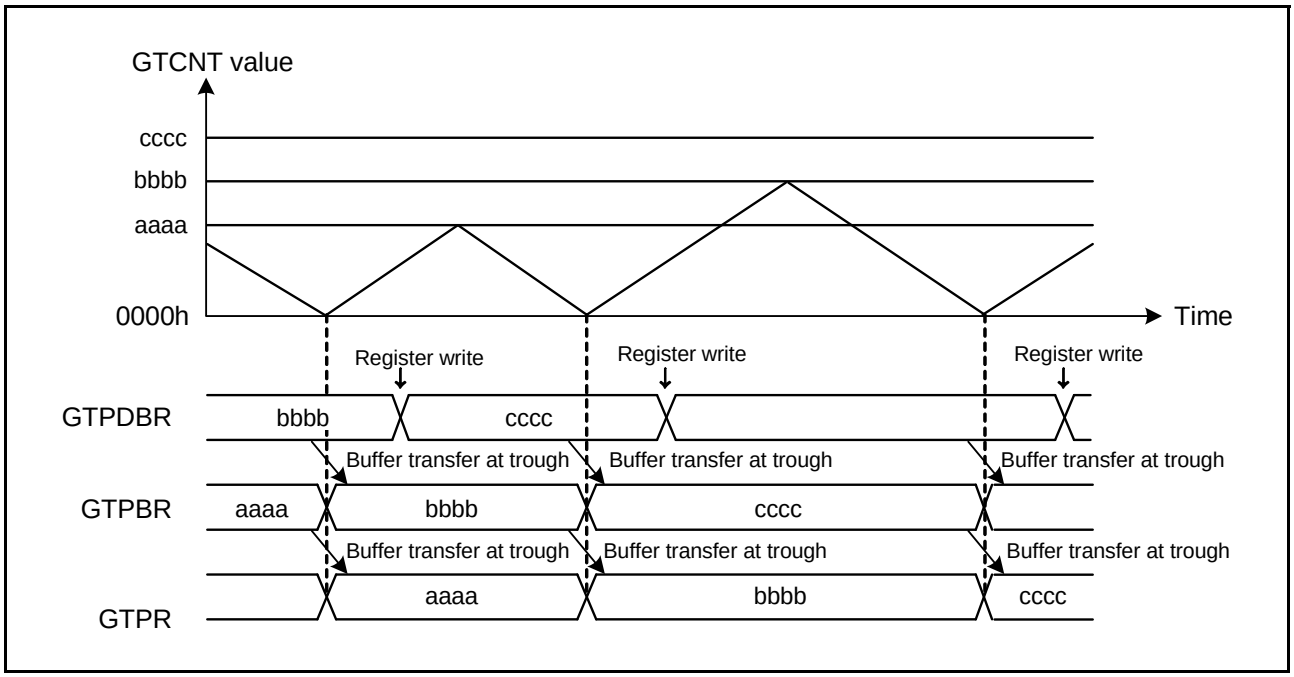


Figure 18.15 Example of GTPR Double Buffer Operation (Triangle Waves)

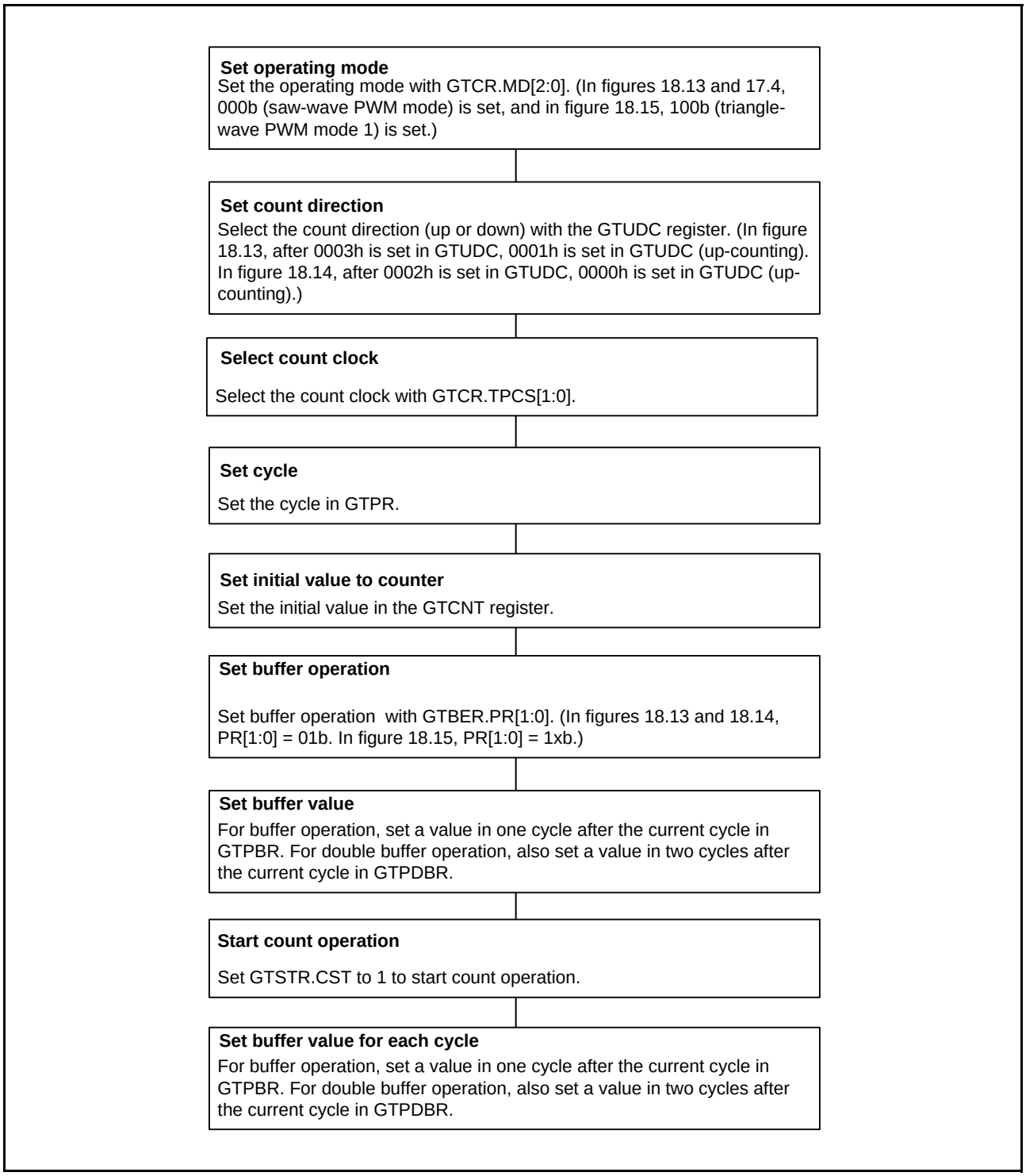


Figure 18.16 Example for Setting GTPR Buffer Operation

18.3.2.2 Buffer Operation for GTCCRA and GTCCRB

GTCCRC can function as the GTCCRA buffer register and GTCCRD can function as the GTCCRC buffer register (double-buffer register for GTCCRA). Similarly, GTCCRE can function as the GTCCRB buffer register and GTCCRF can function as the GTCCRE buffer register (double-buffer register for GTCCRB).
To set GTCCRA or GTCCRB to function as a double buffer, set GTBER.CCRA[1:0] or GTBER.CCRB[1:0] to 10b or 11b. For single buffer operation, set 01b. Not to function as buffer, set 00b.

(1) When GTCCRA or GTCCRB Functions as Output Compare Register

Buffer transfer is performed at an overflow (during up-count operation) or an underflow (during down-count operation) in saw-wave mode, and at a trough in triangle-wave mode.
Figure 18.17 to Figure 18.19 show examples of GTCCRA and GTCCRB buffer operation and Figure 18.20 shows an example for setting GTCCRA and GTCCRB buffer operation.

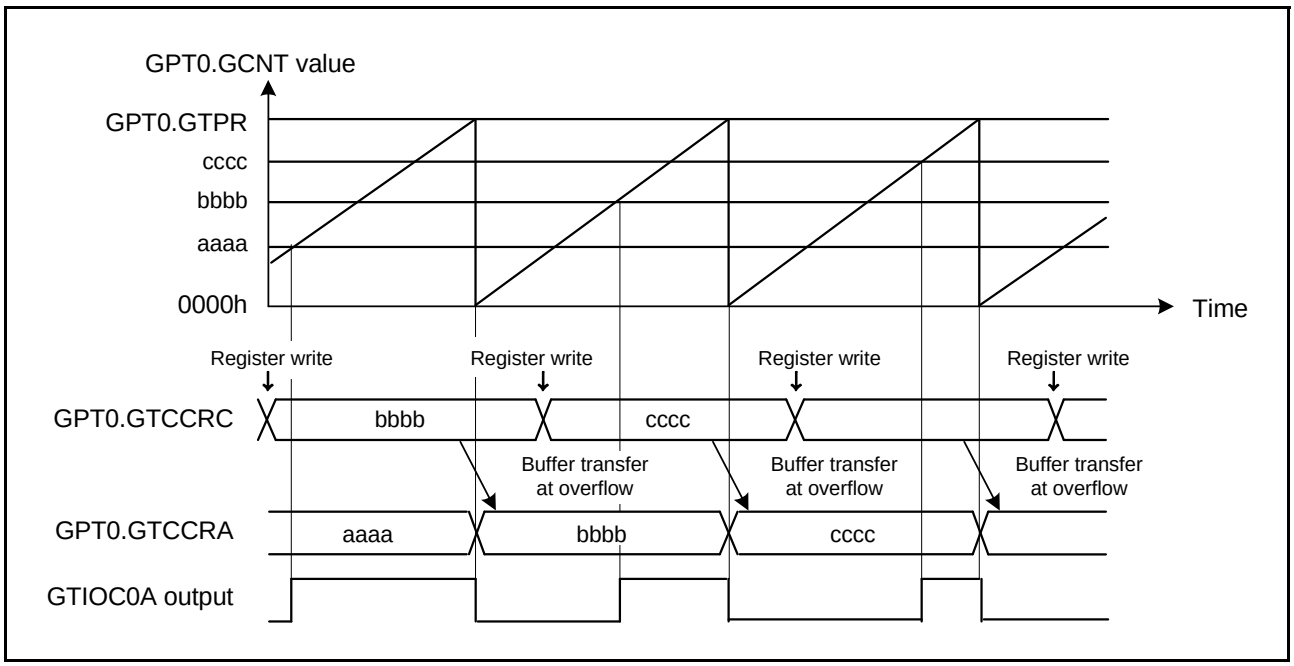


Figure 18.17 Example of GTCCRA and GTCCRB Buffer Operation (Output Compare, Saw Waves in Up-Count Operation, High Output at GTCCRA Compare Match, Low Output at Cycle End)

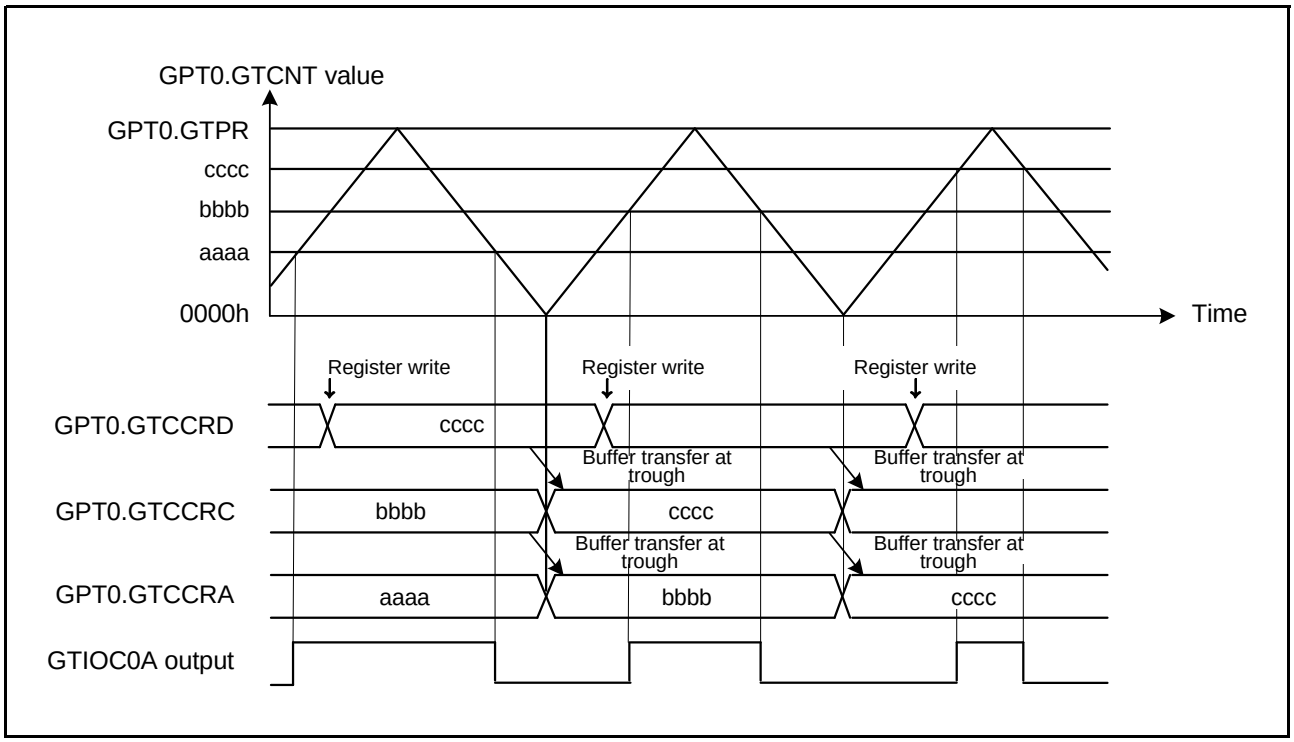


Figure 18.18 Example of GTCCRA and GTCCRB Double Buffer Operation (Output Compare, Triangle Waves, Buffer Operation at Trough, Toggle Output at GTCCRA Compare Match, Output Retained at Cycle End)

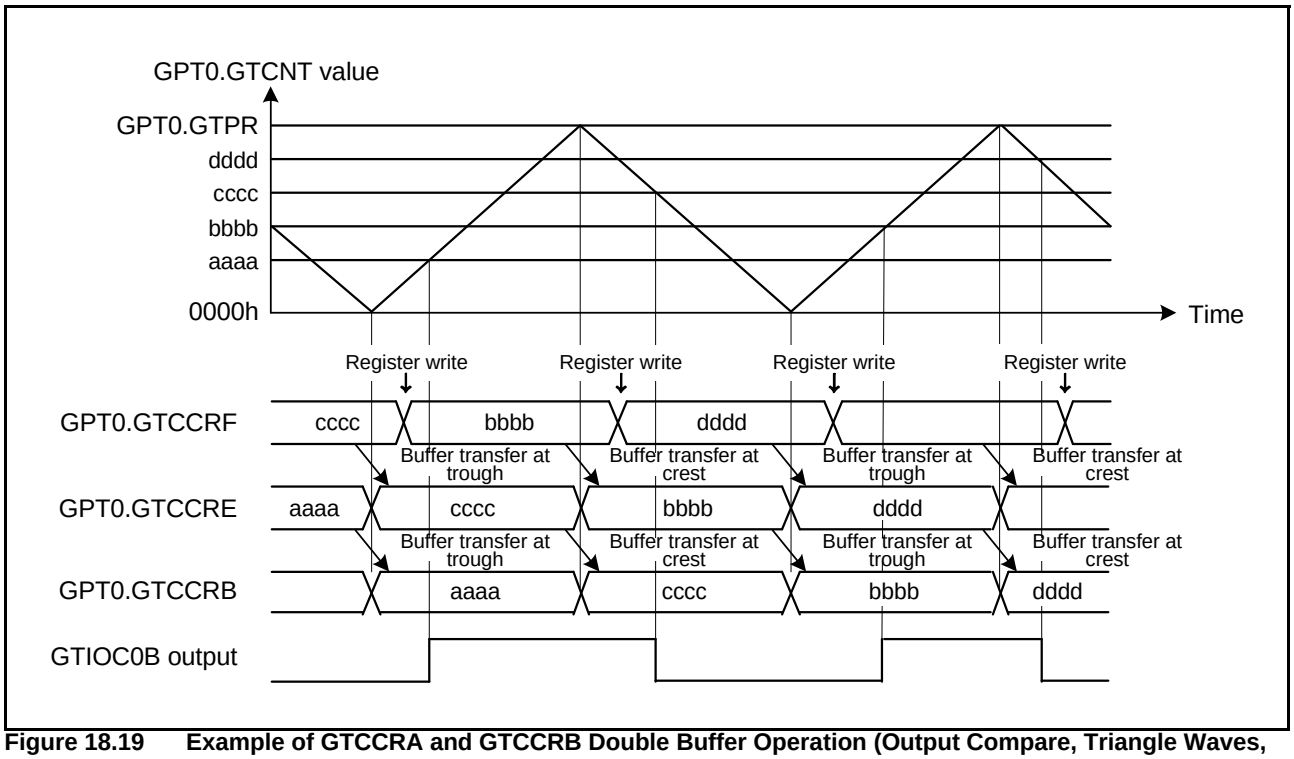


Figure 18.19 Example of GTCCRA and GTCCRB Double Buffer Operation (Output Compare, Triangle Waves, Buffer Operation at Both Troughs and Crests, Toggle Output at GTCCRB Compare Match, Output Retained at Cycle End)

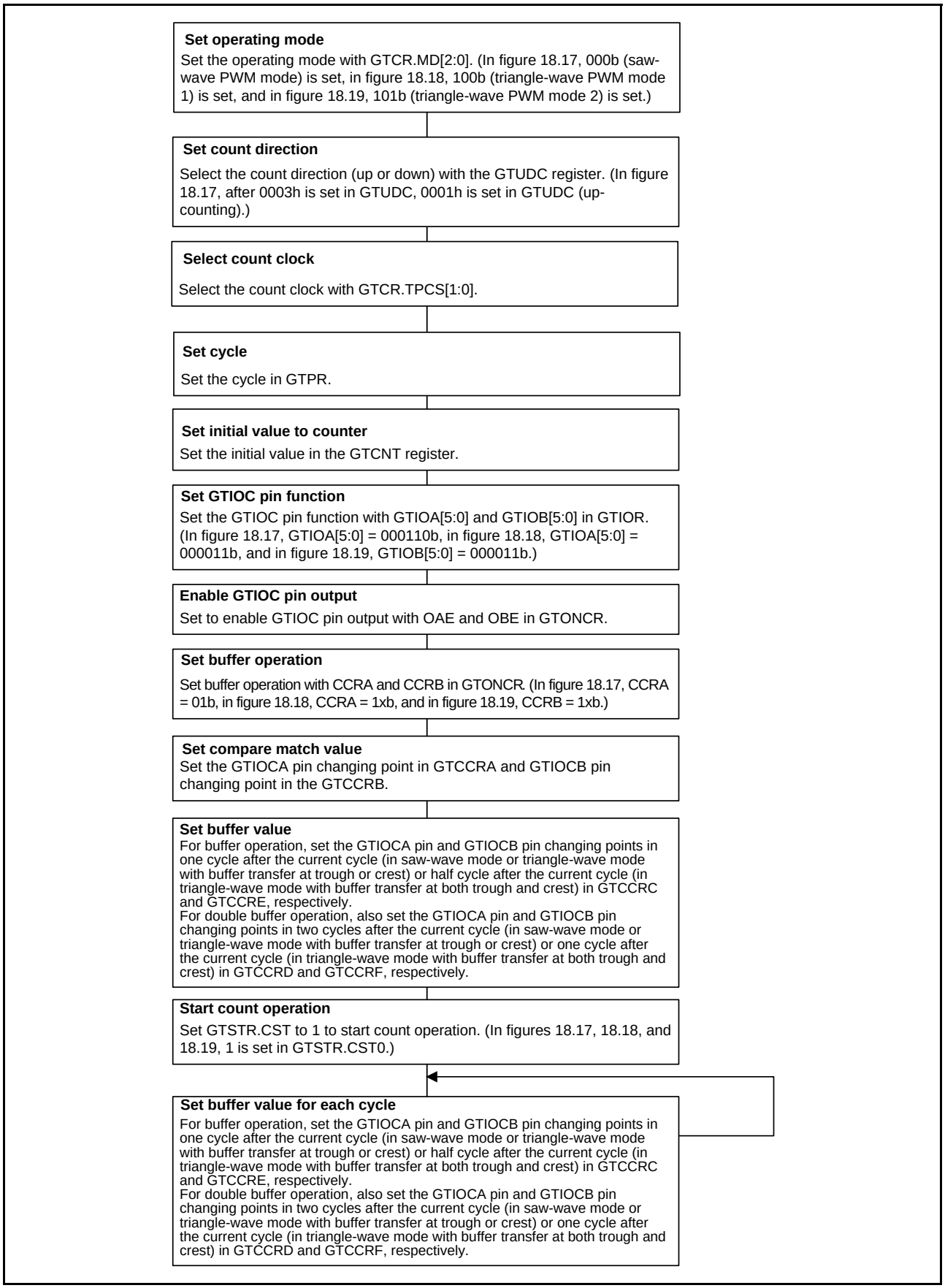


Figure 18.20 Example for Setting GTCCRA and GTCCRB Buffer Operation (for Output Compare)

(2) When GTCCRA or GTCCRB Functions as Input Capture Register

Buffer transfer is performed at a point when an input capture is generated. When an input capture is generated, the GTCNT counter value is transferred to GTCCRA and GTCCRB and the stored GTCCRA and GTCCRB register values are transferred to buffer registers.

Figure 18.21 and Figure 18.22 show examples of GTCCRA and GTCCRB buffer operation and Figure 18.23 shows an example for setting GTCCRB buffer operation.

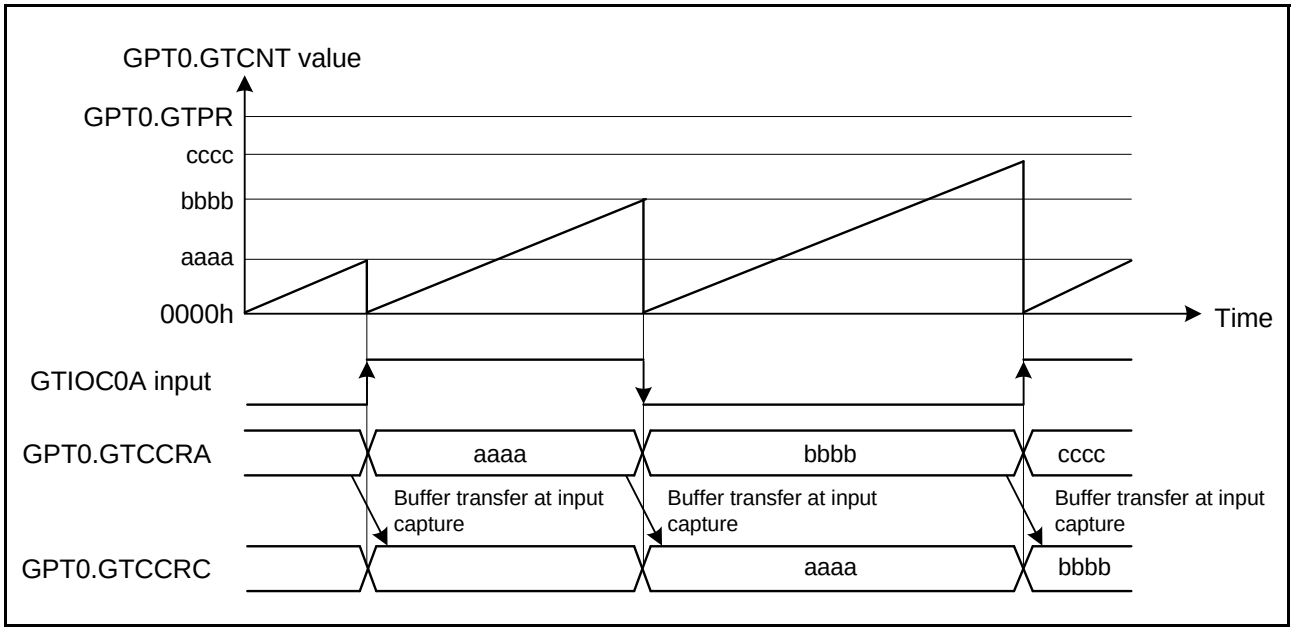


Figure 18.21 Example of GTCCRA and GTCCRB Buffer Operation (Input Capture at Both Edges of GTIOC0A Input, Saw Waves in Up-Count Operation, GTCNT Counter Cleared at GTCCRA Input Capture)

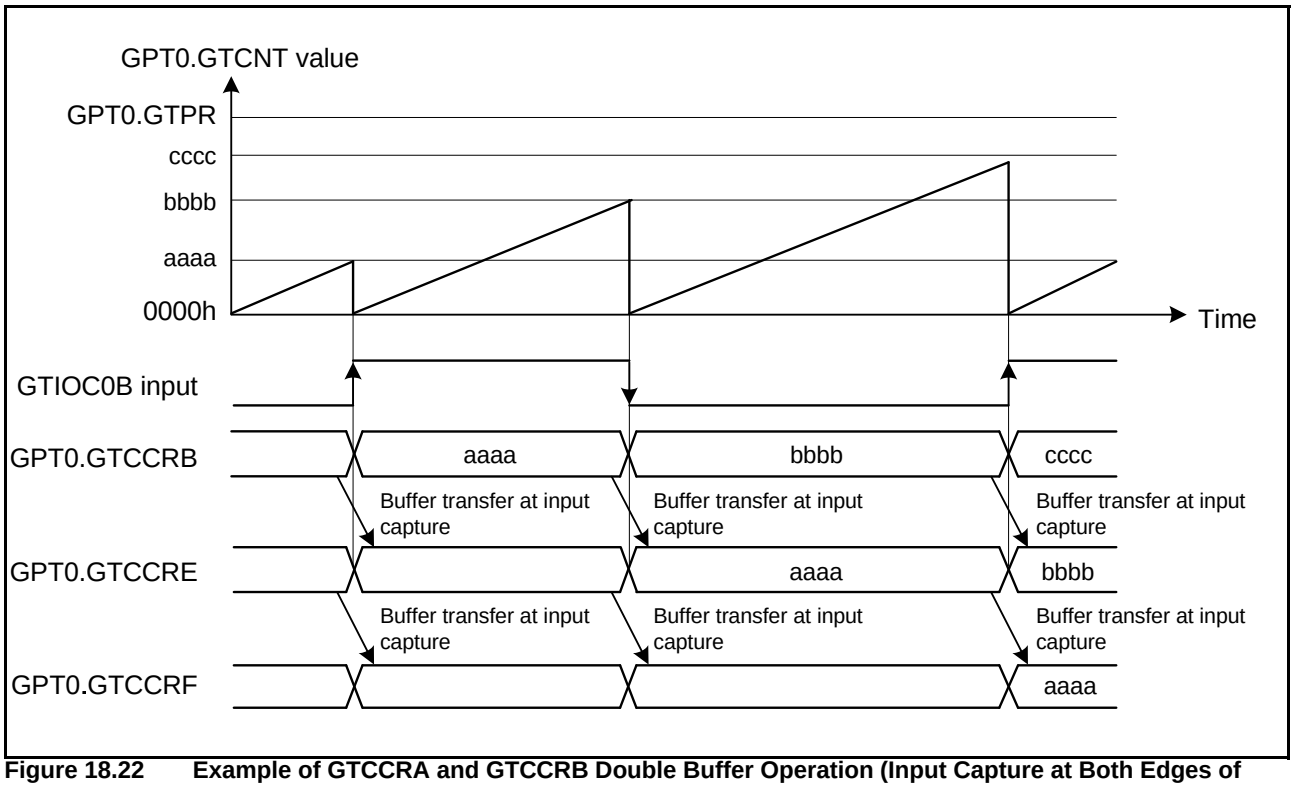


Figure 18.22 Example of GTCCRA and GTCCRB Double Buffer Operation (Input Capture at Both Edges of GTIOC0B Input, Saw Waves in Up-Count Operation, GTCNT Counter Cleared at GTCCRB Input Capture)

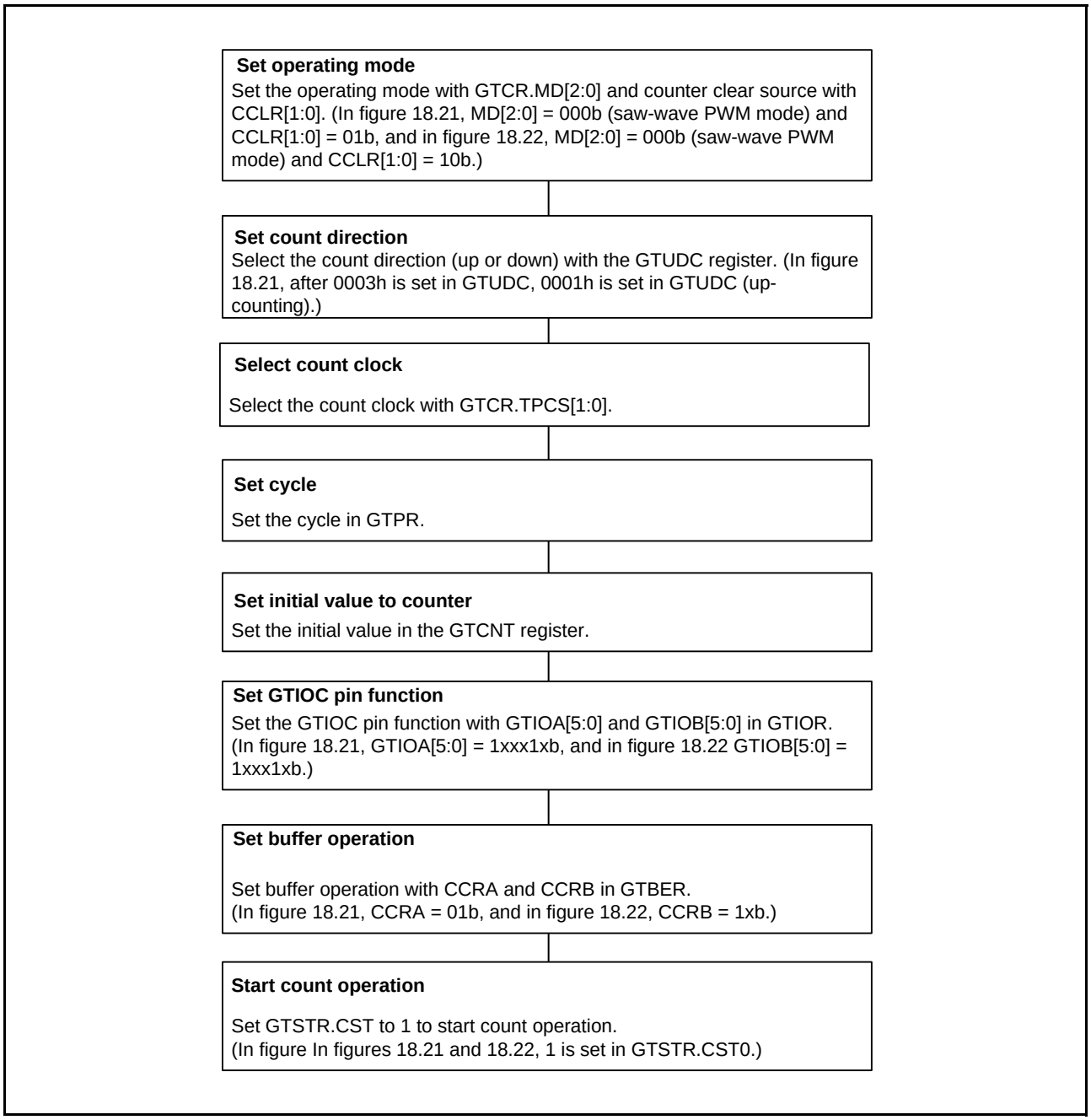


Figure 18.23 Example for Setting GTCCRA and GTCCRB Buffer Operation (for Input Capture)

18.3.2.3 Buffer Operation for GTADTRA and GTADTRB

GTADTBRA can function as the GTADTRA buffer register and GTADTDBRA can function as the GTADTBRA buffer register (double-buffer register for GTADTRA). Similarly, GTADTBRB can function as the GTADTRB buffer register and GTADTDBRB can function as the GTADTBRB buffer register (double-buffer register for GTADTRB).
To set GTADTRA or GTADTRB to function as a double buffer, set GTBER.ADTDA or GTBER.ADTDB to 1. For single buffer operation, set 0. Not to function as buffer, set GTBER.ADTTA[1:0] or GTBER.ADTTB[1:0] to 00b.
The buffer transfer timing can be set with the GTBER.ADTTA[1:0] bits. For saw waves, overflows (during up-count operation) or underflows (during down-count operation) can be selected. For triangle waves, crests are selected when GTBER.ADTTA[1:0] = 01b, troughs are selected when GTBER.ADTTA[1:0] = 10b, and both crests and troughs are selected when GTBER.ADTTA[1:0] = 00b.
Figure 18.24 to Figure 18.26 show examples of GTADTRA and GTADTRB buffer operation and Figure 18.27 shows an example for setting GTDTRA and GTADTRB buffer operation.

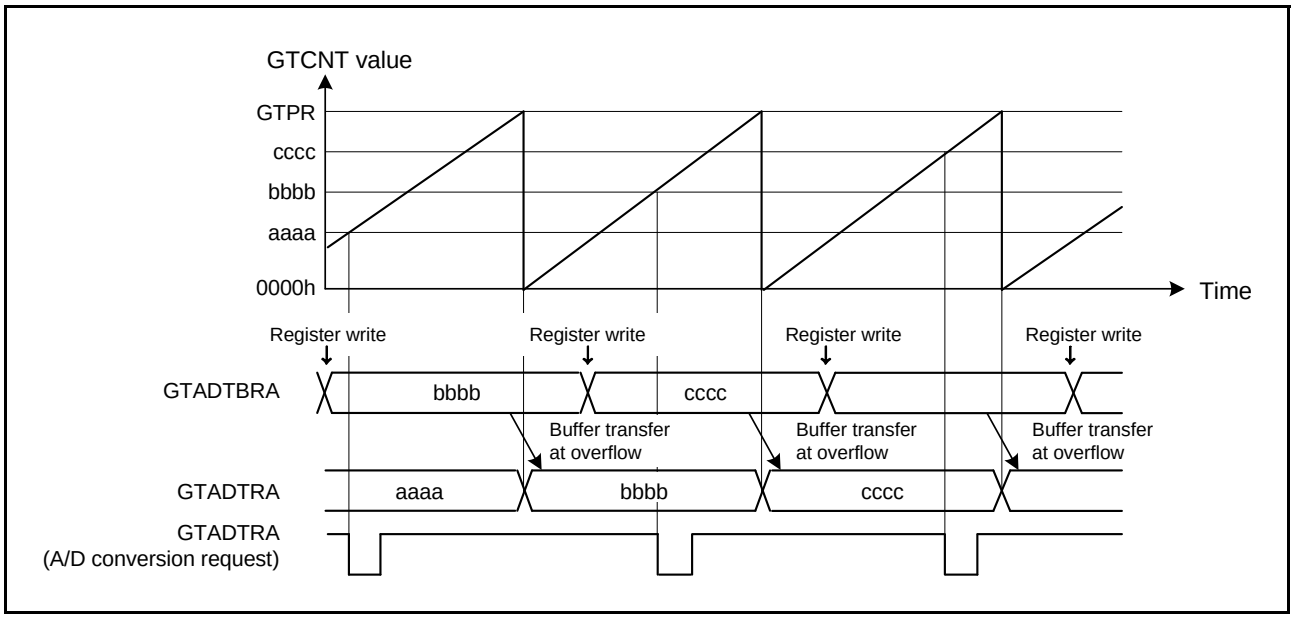


Figure 18.24 Example of GTADTRA and GTADTRB Buffer Operation (Saw Waves in Up-Count Operation, A/D Converter Start Request Generated by Up-Counting)

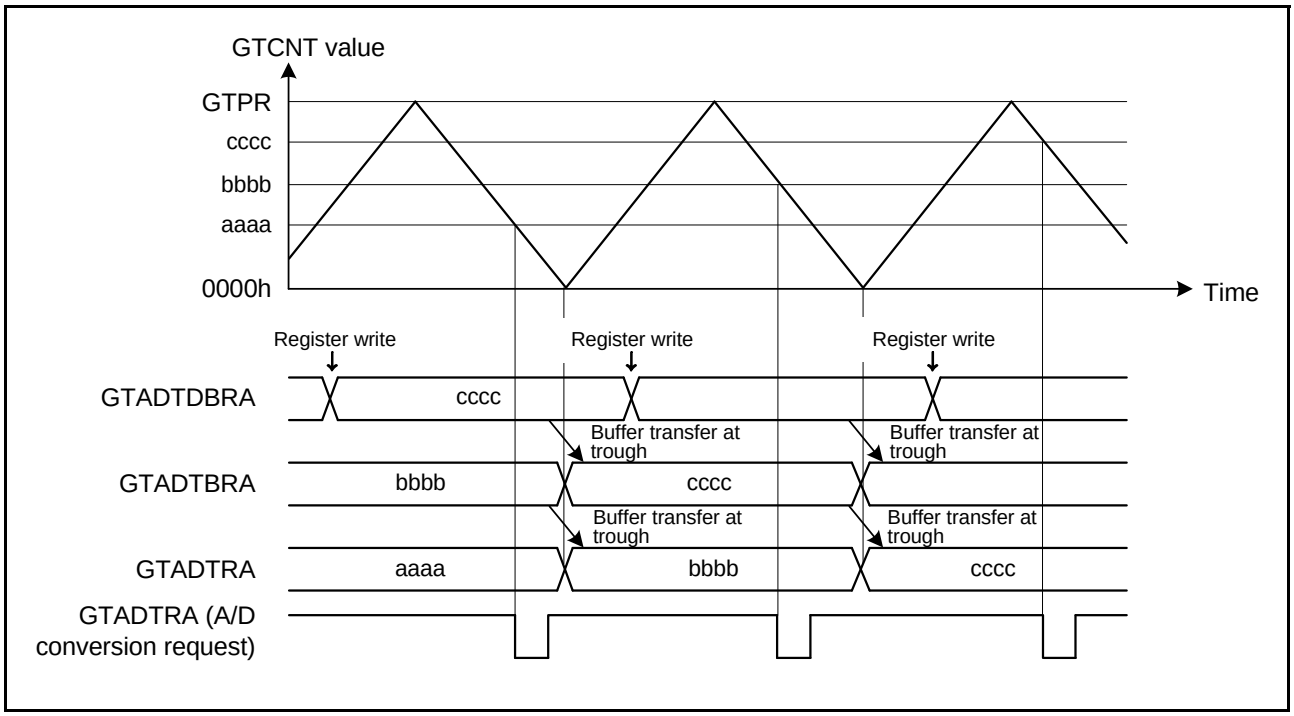


Figure 18.25 Example of GTADTRA and GTADTRB Double Buffer Operation (Triangle Waves, Buffer Transfer at Troughs, A/D Converter Start Request Generated by Down-Counting)

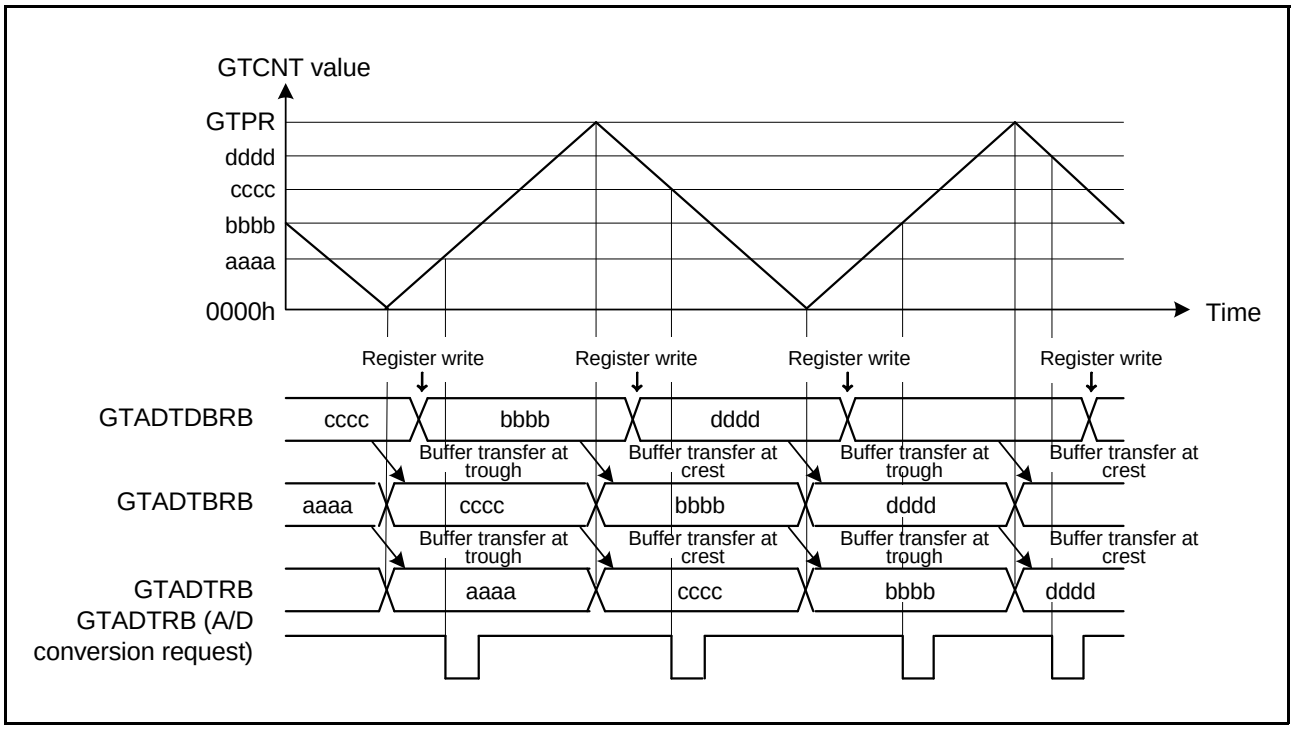


Figure 18.26 Example of GTADTRA and GTADTRB Double Buffer Operation (Triangle Waves, Buffer Transfer at Both Troughs and Crests, A/D Converter Start Request Generated by Both Up- and Down-Counting)

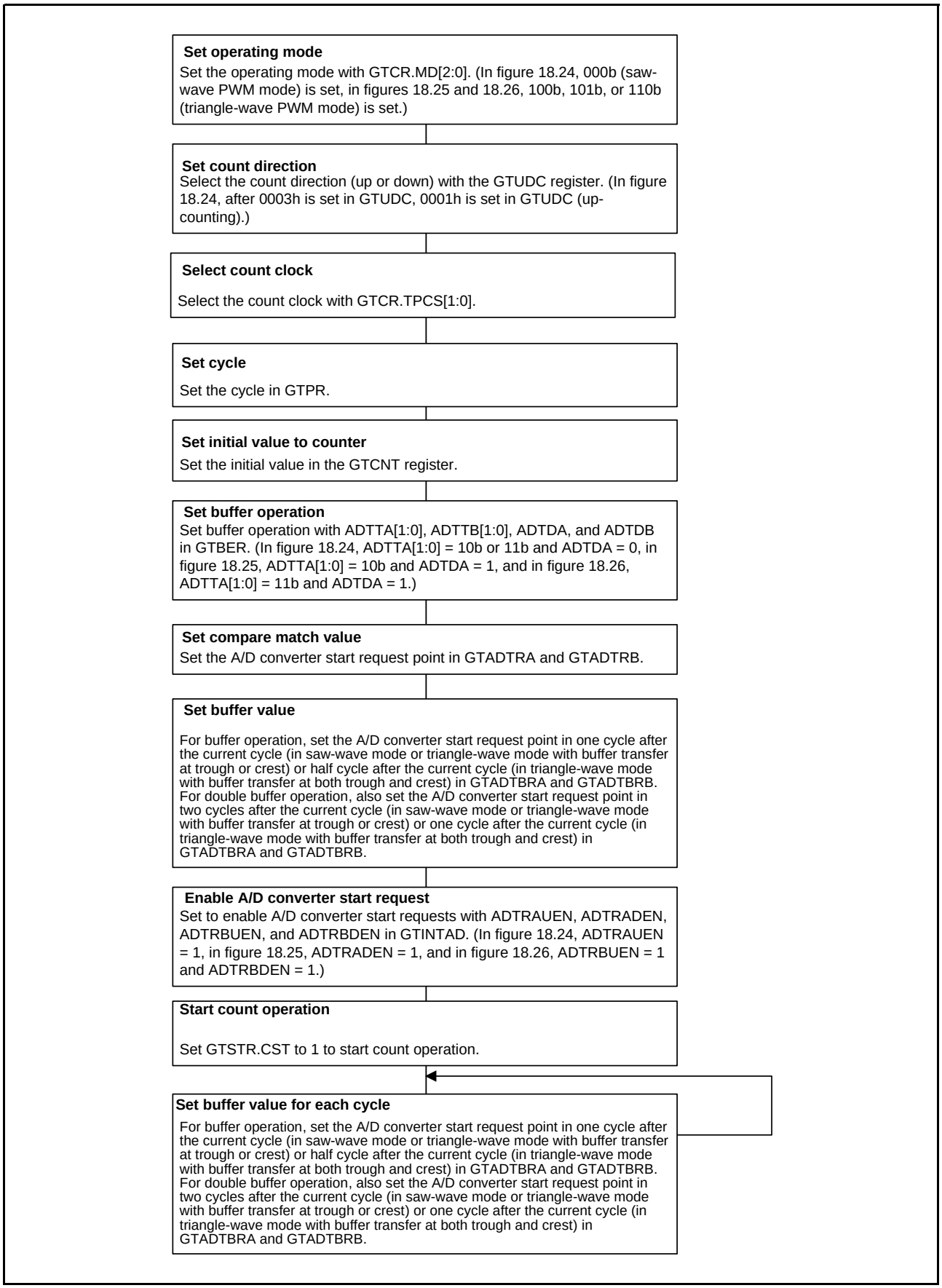


Figure 18.27 Example for Setting GTADTRA and GTADTRB Buffer Operation

18.3.3 PWM Output Operating Mode

The GPT can output PWM waveforms to the GTIOCnA pin or GTIOCnB pin by a compare match between the GPTn.CTCNT counter and GPTn.GTCCRA or GPTn.GTCCRB (n: channel number). An operating mode can be set independently for each channel, and synchronized operation on channels is also possible.
By setting GTDTCR, GTDVU, and GTDVD, the compare match value for a negative-phase waveform with dead time can automatically be set to GTCCRB.

(1) Saw-Wave PWM Mode (GTCR.MD = 000b)

In saw-wave PWM mode, GPTn.GTCNT performs saw-wave (half-wave) operation by setting the cycle in GTPR and a PWM waveform is output to the GTIOCnA or GTIOCnB pin when a GPTn.GTCCRA or GPTn.GTCCRB compare match occurs (n: channel number). The pin output value can be selected from low output, high output, or toggle output separately for a compare match and for the cycle end according to the GTIOR setting
Figure 18.28 shows an example of saw-wave PWM mode operation, and Figure 18.29 shows an example for setting saw-wave PWM mode.

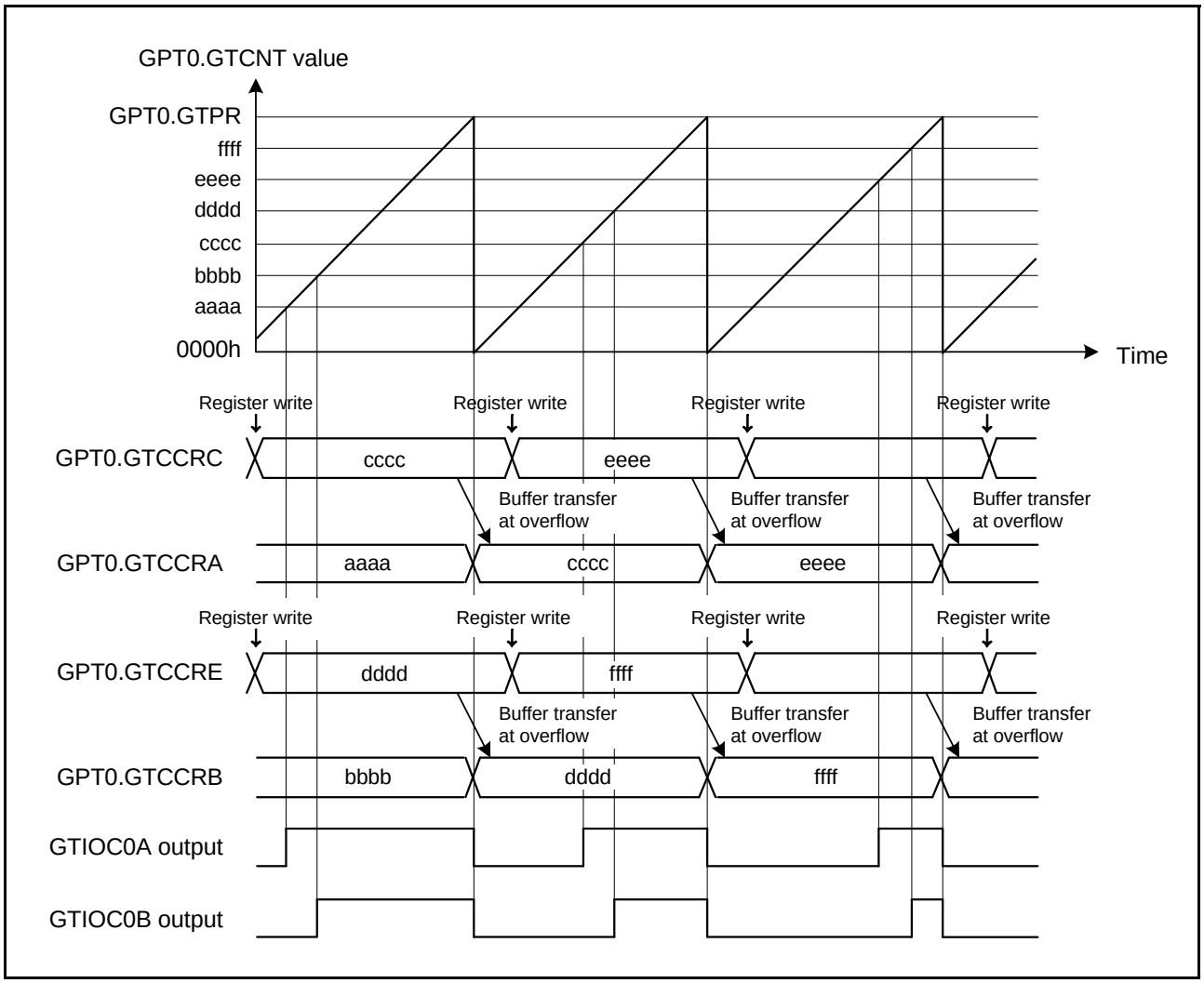


Figure 18.28 Example of Saw-Wave PWM Mode Operation (Up-Count Operation, Buffer Operation, High Output at GTCCRA/GTCCRB Compare Match, Low Output at Cycle End)

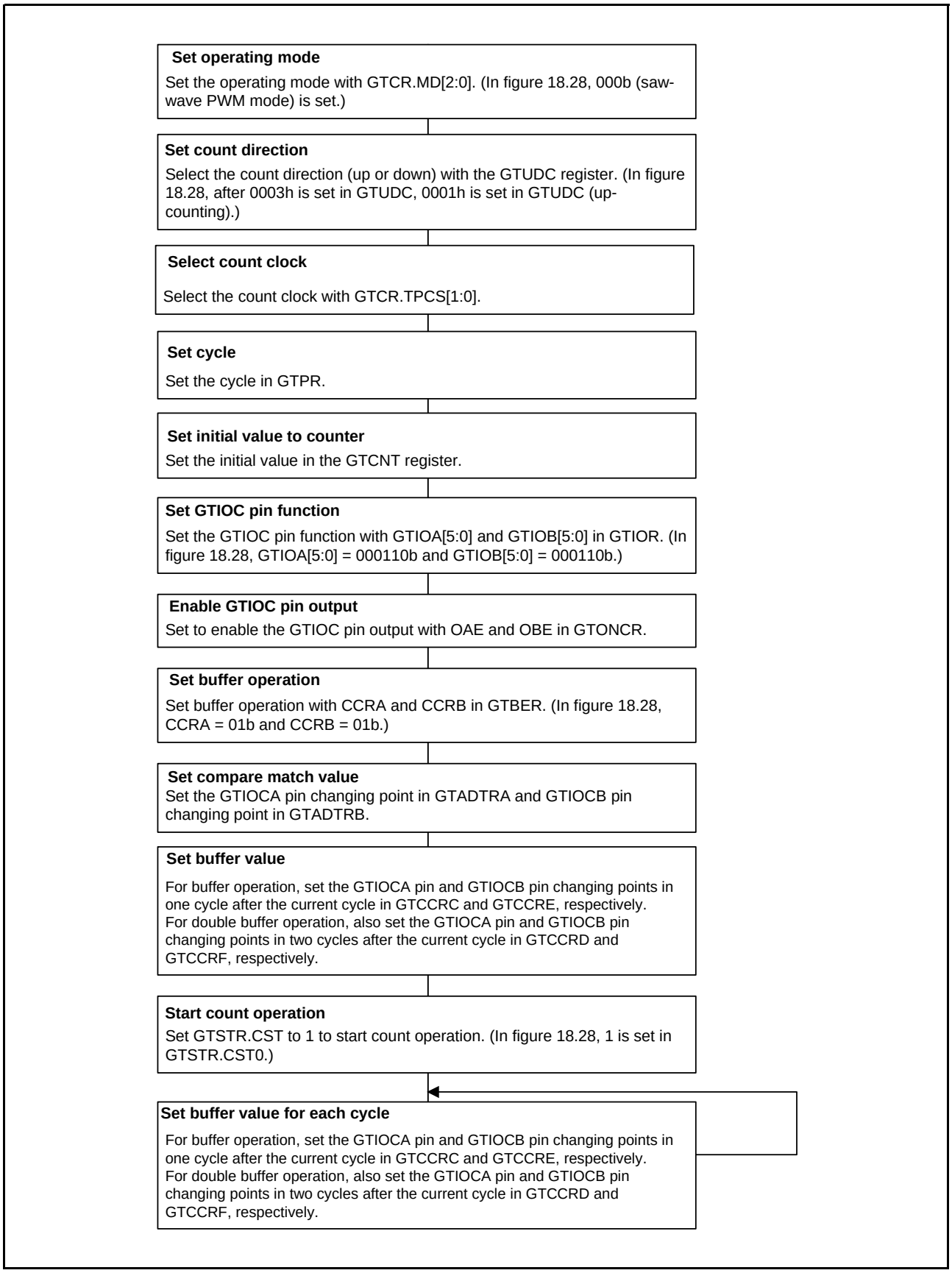


Figure 18.29 Example for Setting Saw-Wave PWM Mode

(2) Saw-Wave One-Shot Pulse Mode

The saw-wave one-shot pulse mode is a mode in which the cycle is set in GPTn.GTPR, the GPTn.GTCNT counter performs saw-wave (half-wave) operation and a PWM waveform is output to the GTIOCnA or GTIOCnB pin at a compare match of GPTn.GTCCRA or GPTn.GTCCRB with buffer operation fixed (n: channel number).

Buffer operation in saw-wave one-shot pulse mode is different from the usual buffer operation. Buffer transfer is performed from GTCCRC to GTCCRA, from GTCCRE to GTCCRB, from GTCCRD to temporary register A, and from GTCCRF to temporary register B at the cycle end, and from temporary register A to GTCCRA at a GTCCRA compare match and from temporary register B to GTCCRB at a GTCCRB compare match. The pin output value can be selected from low output, high output, or toggle output separately for a compare match and the cycle end according to the GTIOR setting.

By setting GTDTCR, GTCVU, and GTDVD, a compare match value for a negative-phase waveform with dead time can automatically be set to GTCCRB.

Figure 18.30 shows an example of saw-wave one-shot pulse mode operation, and Figure 18.31 shows an example for setting saw-wave one-shot pulse mode.

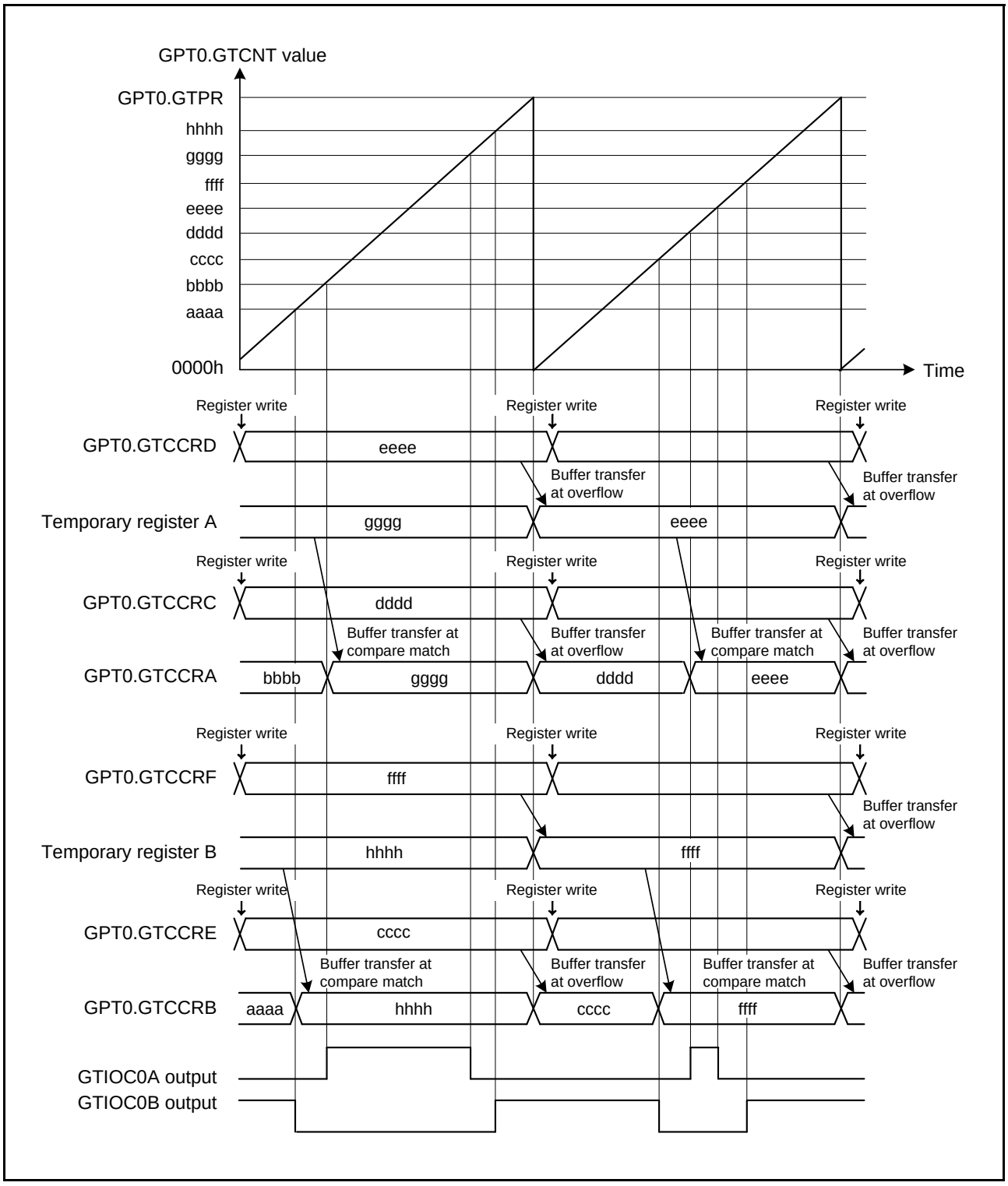


Figure 18.30 Example of Saw-Wave One-Shot Pulse Mode Operation (Up-Count Operation, Low Output from GTIOC0A and High Output from GTIOC0B at Count Start, Toggle Output at GTCCRA/GTCCRB Compare Match, Output Retained at Cycle End)

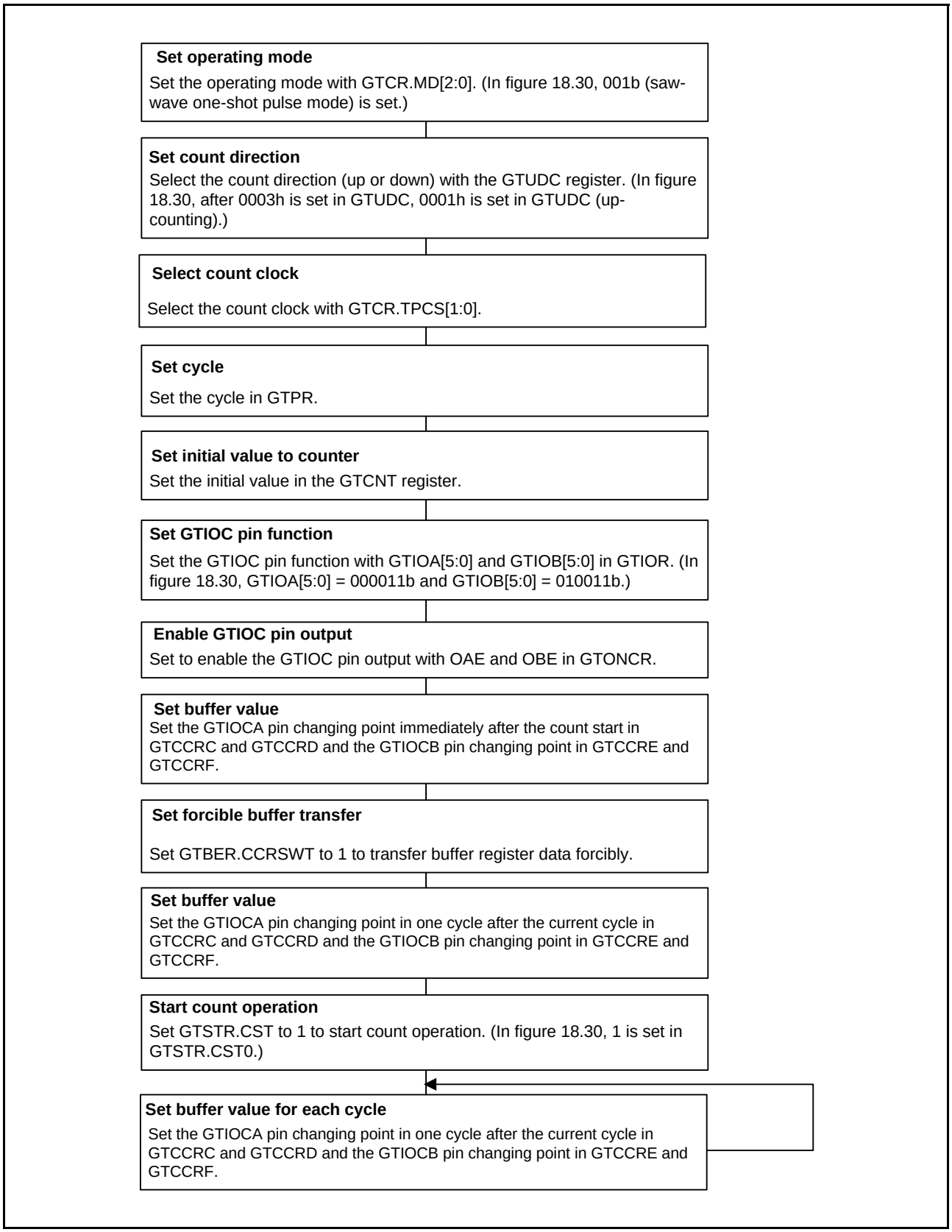


Figure 18.31 Example for Setting Saw-Wave One-Shot Pulse Mode

(3) Triangle-Wave PWM Mode 1 (16-Bit Transfer at Trough)

The triangle-wave PWM mode 1 is a mode in which the cycle is set in GPTn.GTPR, the GPTn.GTCNT counter performs triangle-wave (full-wave) operation, and a PWM waveform is output to the GTIOCnA or GTIOCnB pin when a GPTn.GTCCRA or GPTn.GTCCRB compare match occurs (n: channel number). Buffer transfer is performed at the trough. The pin output value can be selected from low output, high output, or toggle output separately for a compare match and for the cycle end according to the GTIOR setting.

By setting GTDTCR, GTCVU, and GTDVD, a compare match value for a negative-phase waveform with dead time can automatically be set to GTCCRB.

Figure 18.32 shows an example of triangle-wave PWM mode 1 operation, and Figure 18.33 shows an example for setting triangle-wave PWM mode 1.

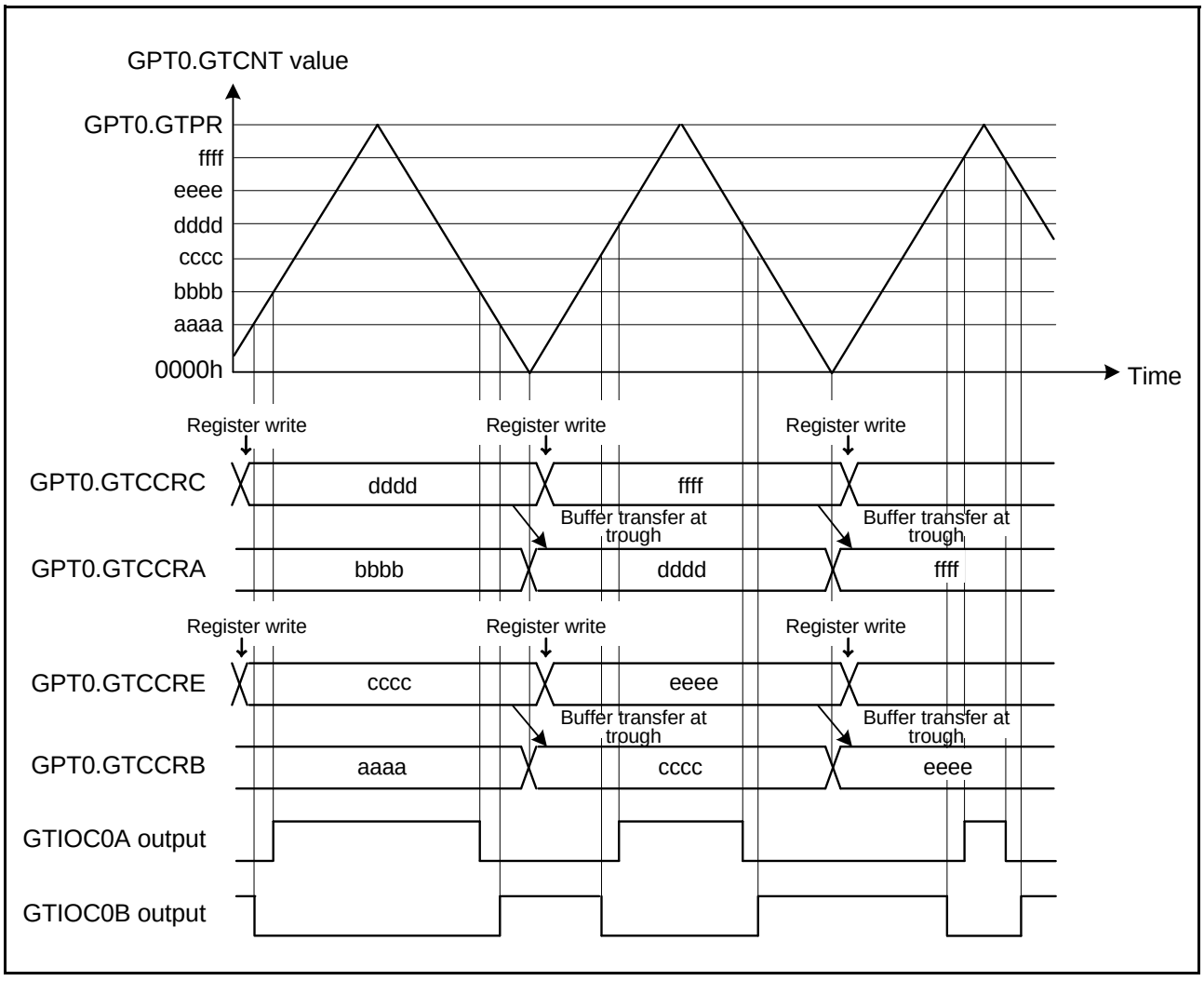


Figure 18.32 Example of Triangle-Wave PWM Mode 1 Operation (Buffer Operation, Low Output from GTIOC0A and High Output from GTIOC0B at Count Start, Toggle Output at GTCCRA/GTCCRB Compare Match, Output Retained at Cycle End)

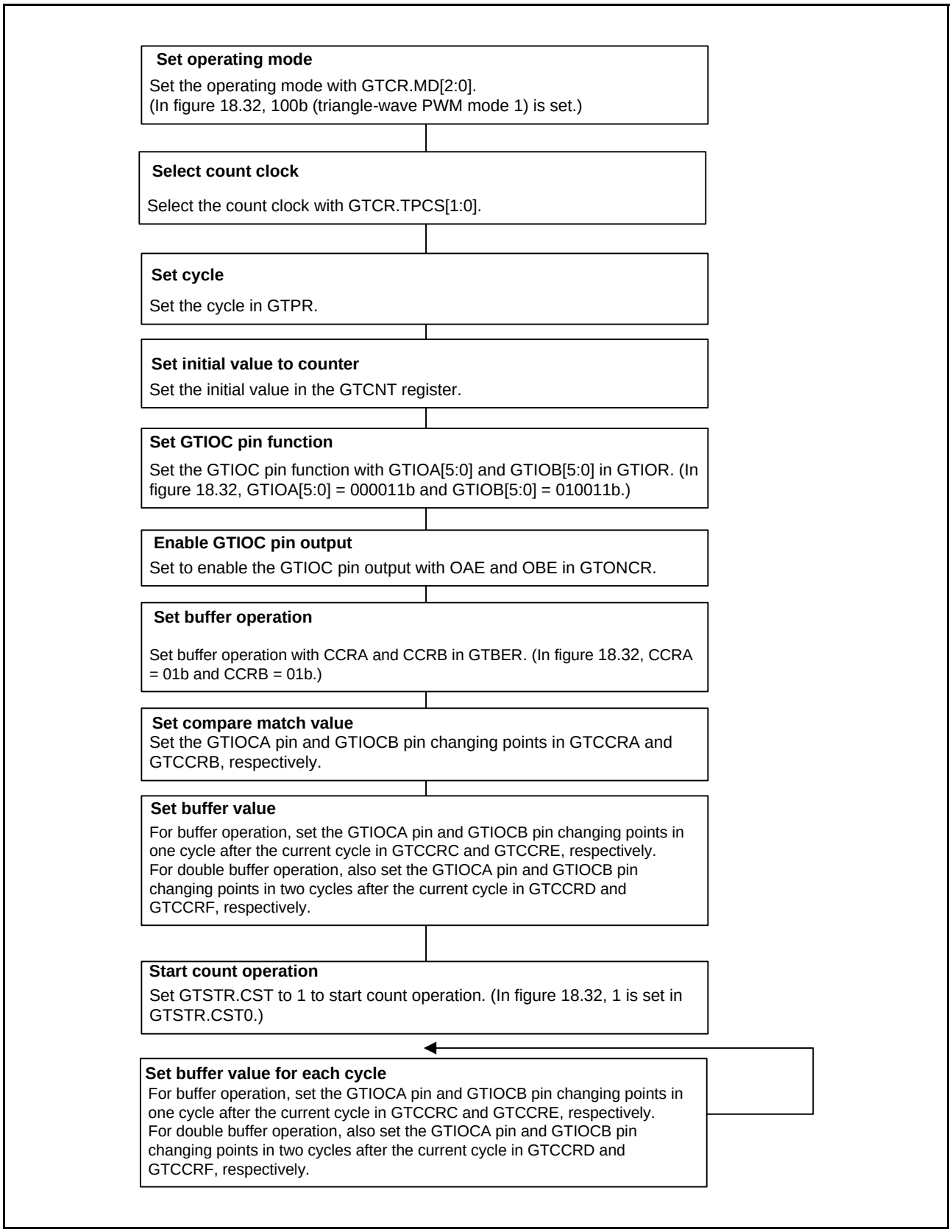


Figure 18.33 Example for Setting Triangle-Wave PWM Mode 1

(4) Triangle-Wave PWM Mode 2 (16-Bit Transfer at Crest and Trough)

Similarly to triangle-wave PWM mode 1, in triangle-wave PWM mode 2 the cycle is set in GPTn.GTPR, the GPTn.GTCNT counter performs triangle-wave (full-wave) operation, and a PWM waveform is output to the GTIOCnA or GTIOCnB pin when a GPTn.GTCCRA or GPTn.GTCCRB compare match occurs (n: channel number). The buffer transfer is performed at both crests and troughs. The pin output value can be selected from low output, high output, or toggle output separately for a compare match and for the cycle end according to the GTIOR setting.
By setting GTDTCR, GTCVU, and GTDVD, a compare match value for a negative-phase waveform with dead time can automatically be set to GTCCRB.
Figure 18.34 shows an example of triangle-wave PWM mode 2 operation, and Figure 18.35 shows an example for setting triangle-wave PWM mode 2.

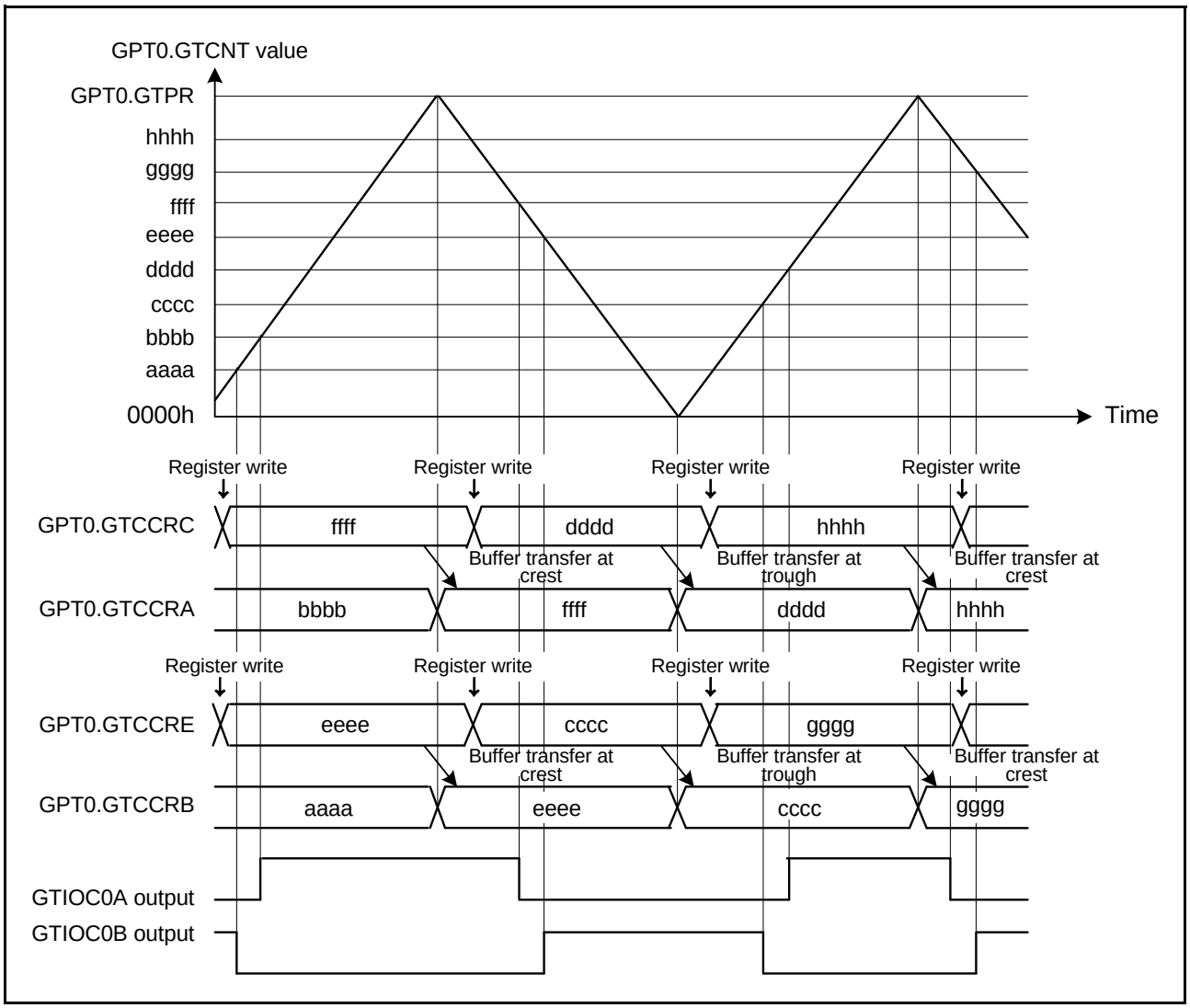


Figure 18.34 Example of Triangle-Wave PWM Mode 2 Operation (Buffer Operation, Low Output from GTIOC0A and High Output from GTIOC0B at Count Start, Toggle Output at GTCCRA/GTCCRB Compare Match, Output Retained at Cycle End)

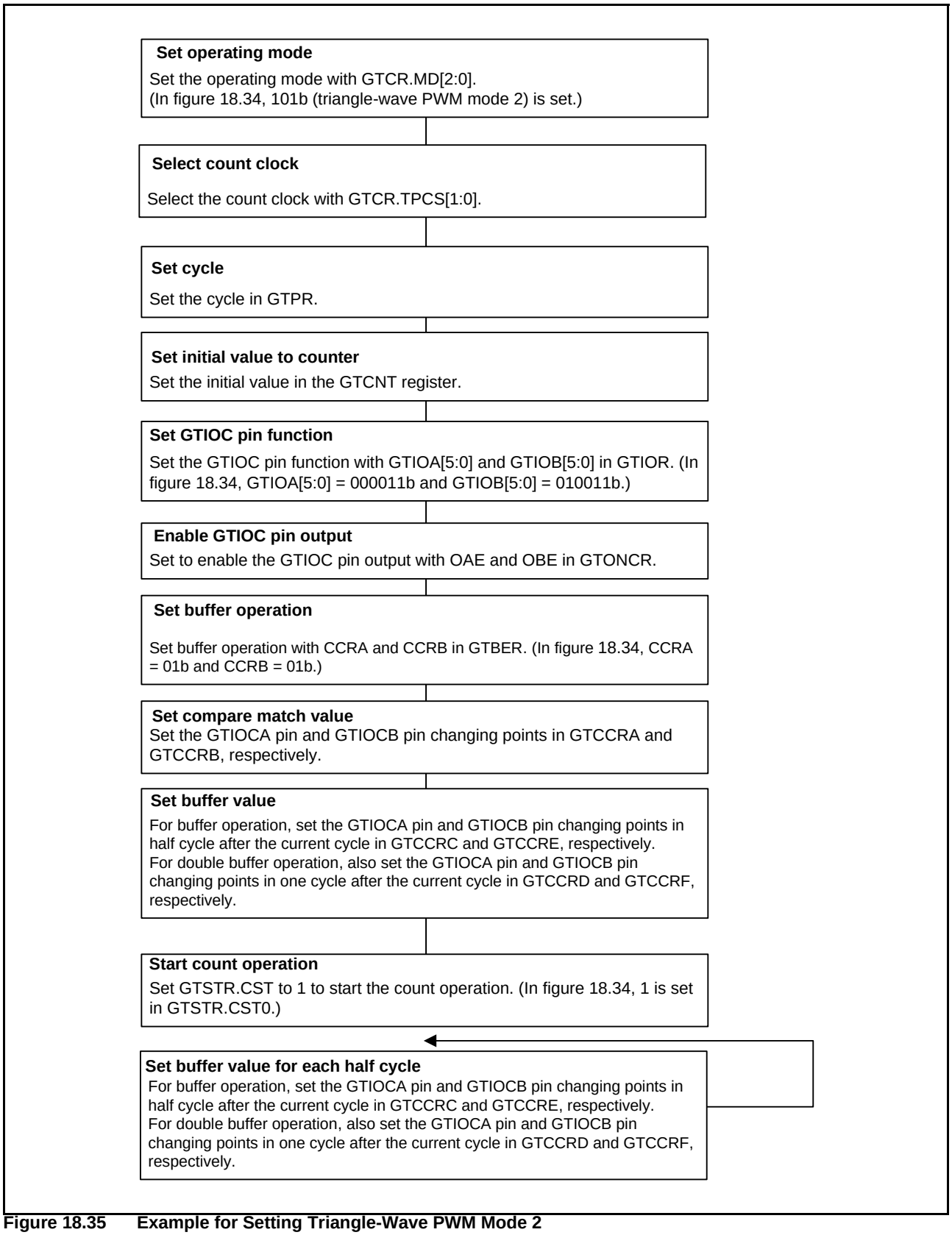


Figure 18.35 Example for Setting Triangle-Wave PWM Mode 2

(5) Triangle-Wave PWM Mode 3 (32-Bit Transfer at Trough)

The triangle-wave PWM mode 3 is a mode in which the cycle is set in GPTn.GTPR, the GPTn.GTCNT counter performs triangle-wave (full-wave) operation and a PWM waveform is output to the GTIOCnA or GTIOCnB pin at a compare match of GPTn.GTCCRA or GPTn.GTCCRB with buffer operation fixed (n: channel number). Buffer operation in triangle-wave PWM mode 3 is different from the usual buffer operation. Buffer transfer is performed from GTCCRC to GTCCRA, from GTCCRE to GTCCRB, from GTCCRD to temporary register A, and from GTCCRF to temporary register B at the trough, and from temporary register A to GTCCRA and from temporary register B to GTCCRB at the crest. The pin output value can be selected from low output, high output, or toggle output separately for a compare match and for the cycle end according to the GTIOR setting.

By setting GTDTCR, GTCVU, and GTDVD, a compare match value for a negative-phase waveform with dead time can automatically be set to GTCCRB.

Figure 18.36 shows an example of triangle-wave PWM mode 3 operation, and Figure 18.37 shows an example for setting triangle-wave PWM mode 3.

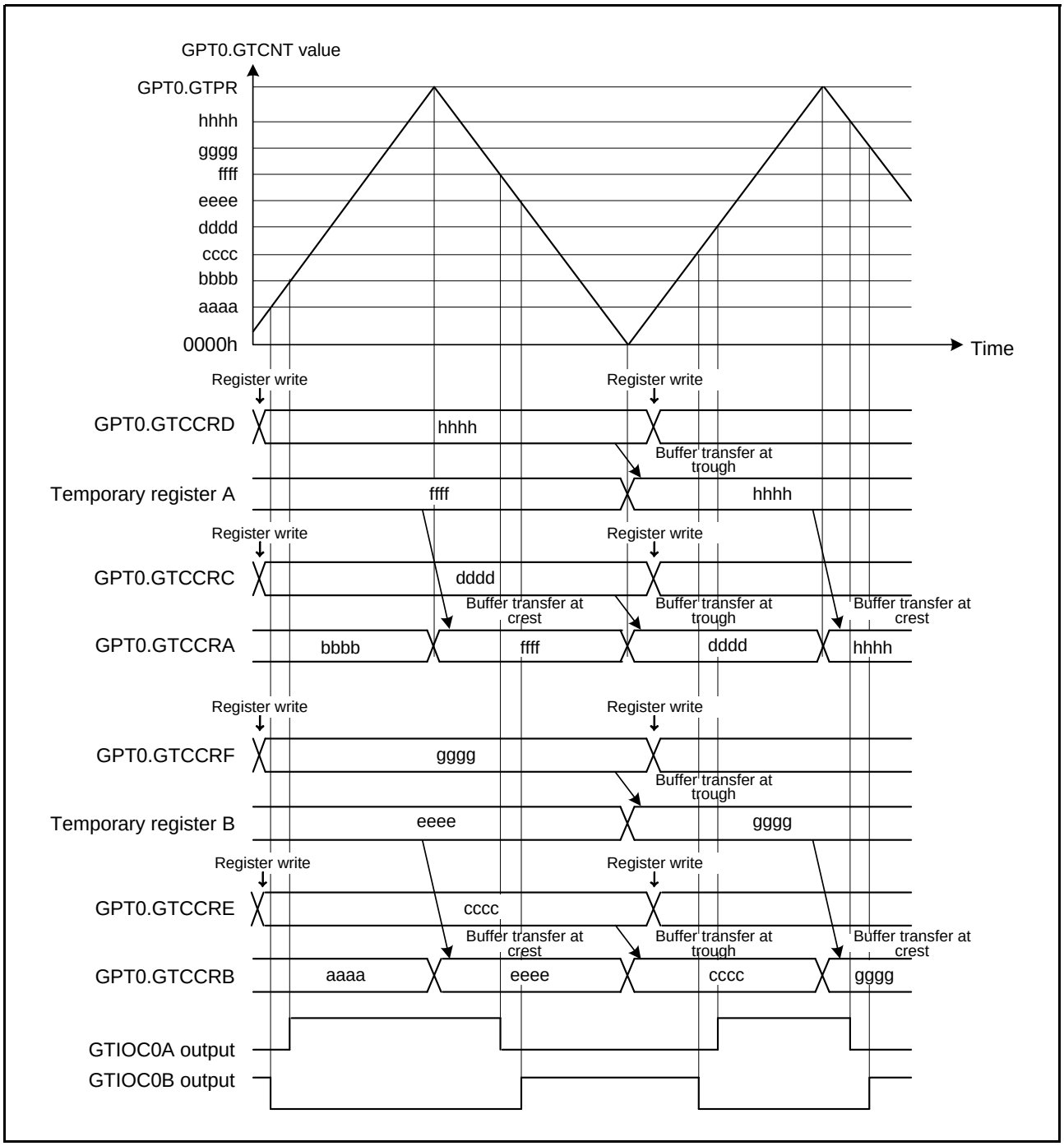


Figure 18.36 Example of Triangle-Wave PWM Mode 3 Operation (Low Output from GTIOC0A and High Output from GTIOC0B at Count Start, Toggle Output at GTCCRA/GTCCRB Compare Match, Output Retained at Cycle End)

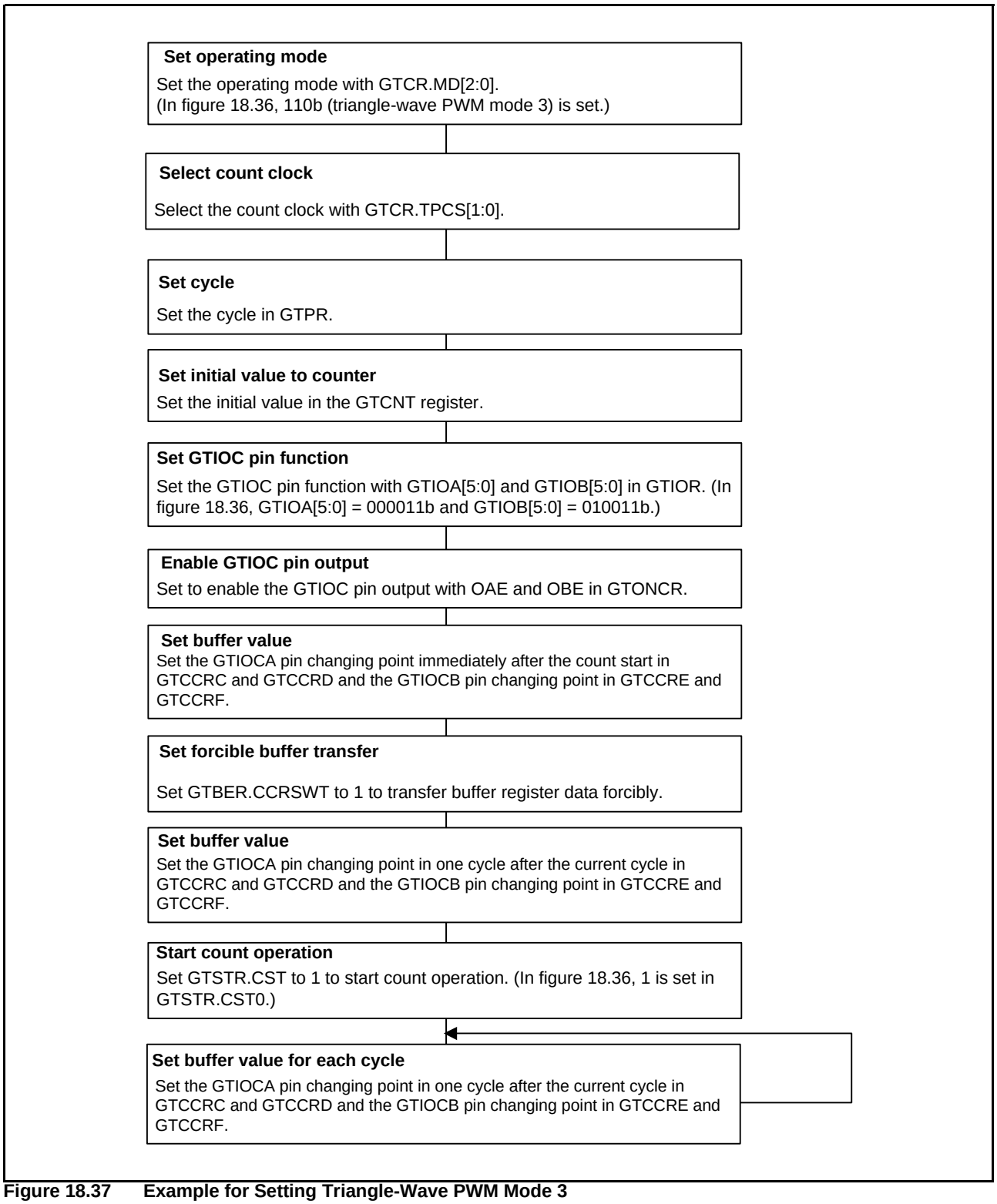


Figure 18.37 Example for Setting Triangle-Wave PWM Mode 3

18.3.4 Automatic Dead Time Setting Function

By setting GTDTCR, a compare match value for a negative waveform with dead time obtained by a compare match value for a positive waveform (GTCCRA value) and specified dead time values (GTDVU and GTDVD values) can automatically be set to GTCCRB.

The automatic dead time setting function can be used in saw-wave one-shot pulse mode and all the triangle PWM modes. Dead time can be separately set for the first half and second half of a waveform. Dead time for the changing point in the first half of a negative waveform is set in GTDVU and that in the second half is set in GTDVD. The same dead time can also be set for the first and second halves.

GTDBU can be used as a buffer register of GTDVU, and GTDBD can be used as a buffer register of GTDVD. Buffer transfer is performed at the cycle end (at a GTCNT overflow (during up-count operation) or an underflow (during down-count operation) for saw waves and at the trough for triangle waves).

Writing to GTCCRB is prohibited when the automatic dead time setting function is used. Dead time setting beyond the cycle is also prohibited. Values for automatic dead time setting can be read from GTCCRB.

Figure 18.38 to Figure 18.40 show examples of automatic dead time setting function operation. Figure 18.41 and 17.42 show the setting examples.

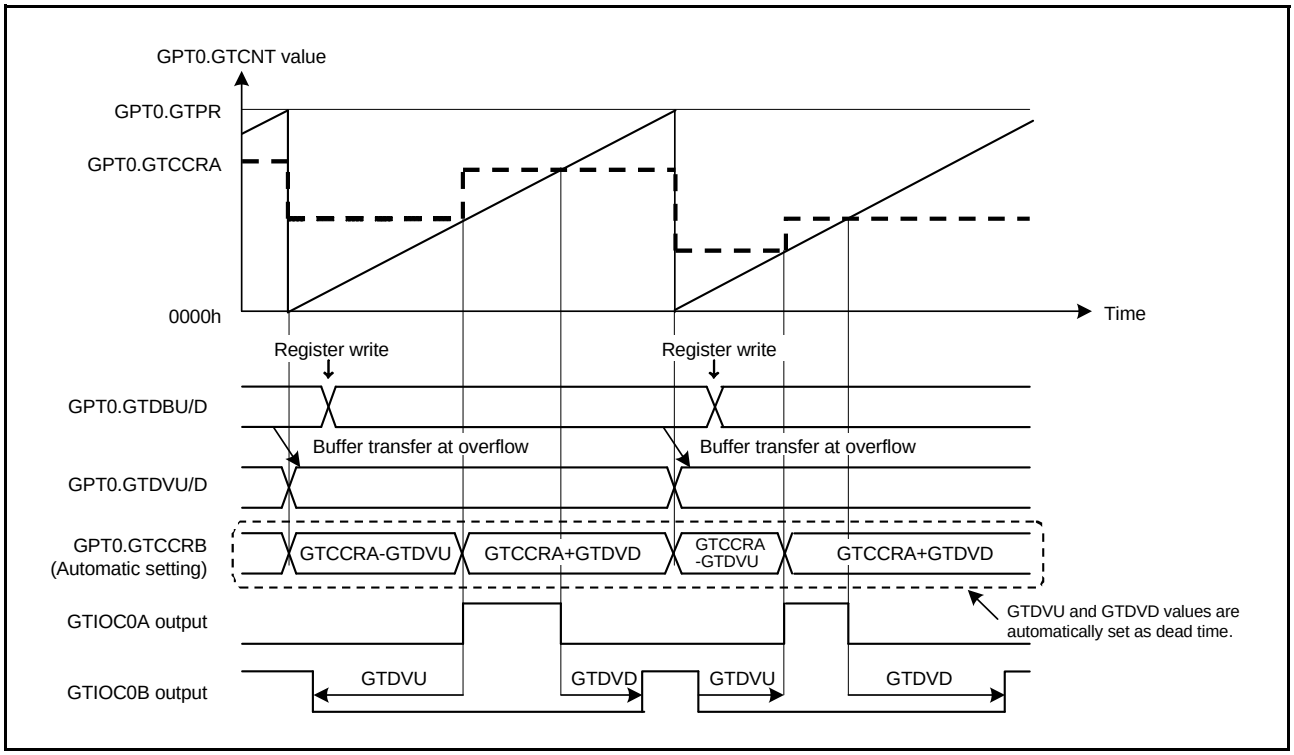


Figure 18.38 Example of Automatic Dead Time Setting Function Operation (Saw-Wave One-Shot Pulse Mode, GTDVU and GTDVD Set to Buffer Operation, Active Level: High)

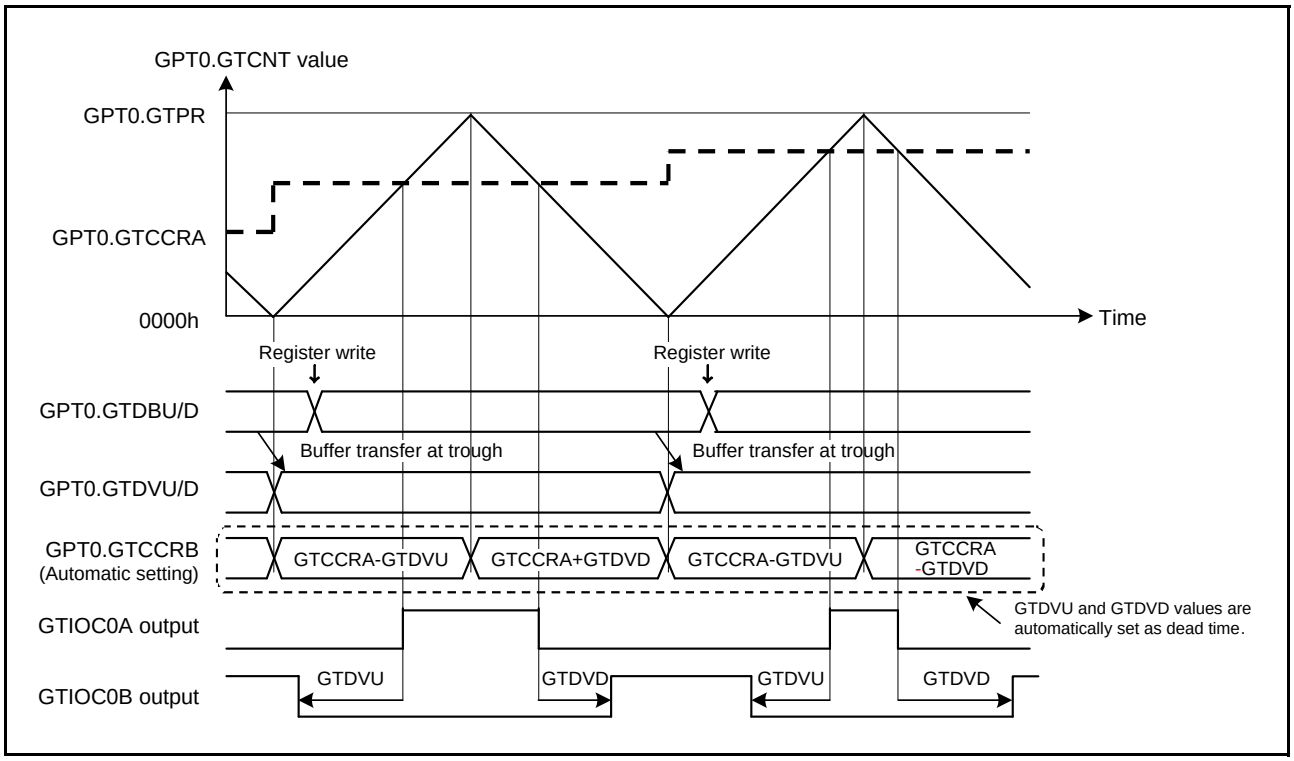


Figure 18.39 Example of Automatic Compare-Match Value Setting Function with Dead Time (Triangle-Wave PWM Mode 1, GTDVU and GTDVD Set to Buffer Operation, Active Level: High)

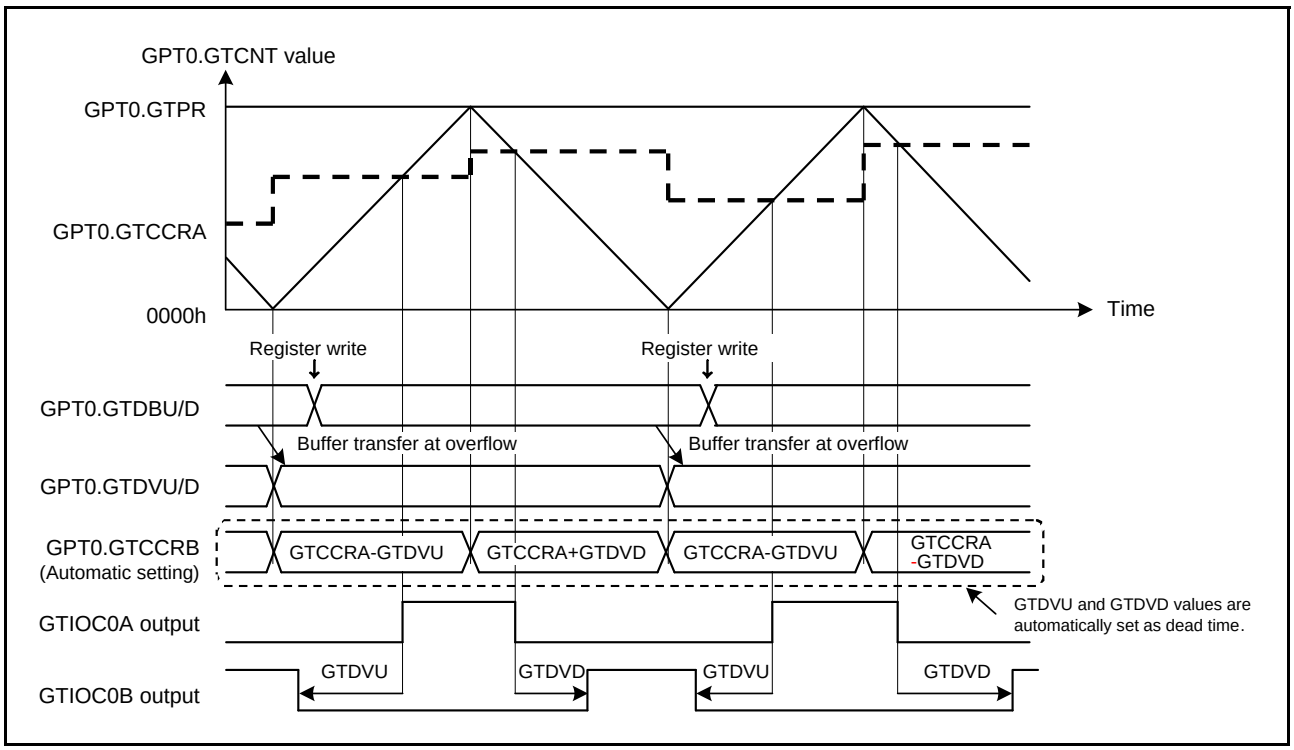


Figure 18.40 Example of Automatic Compare-Match Value Setting Function with Dead Time (Triangle-Wave PWM Mode 2 or 3, GTDVU and GTDVD Set to Buffer Operation, Active Level: High)

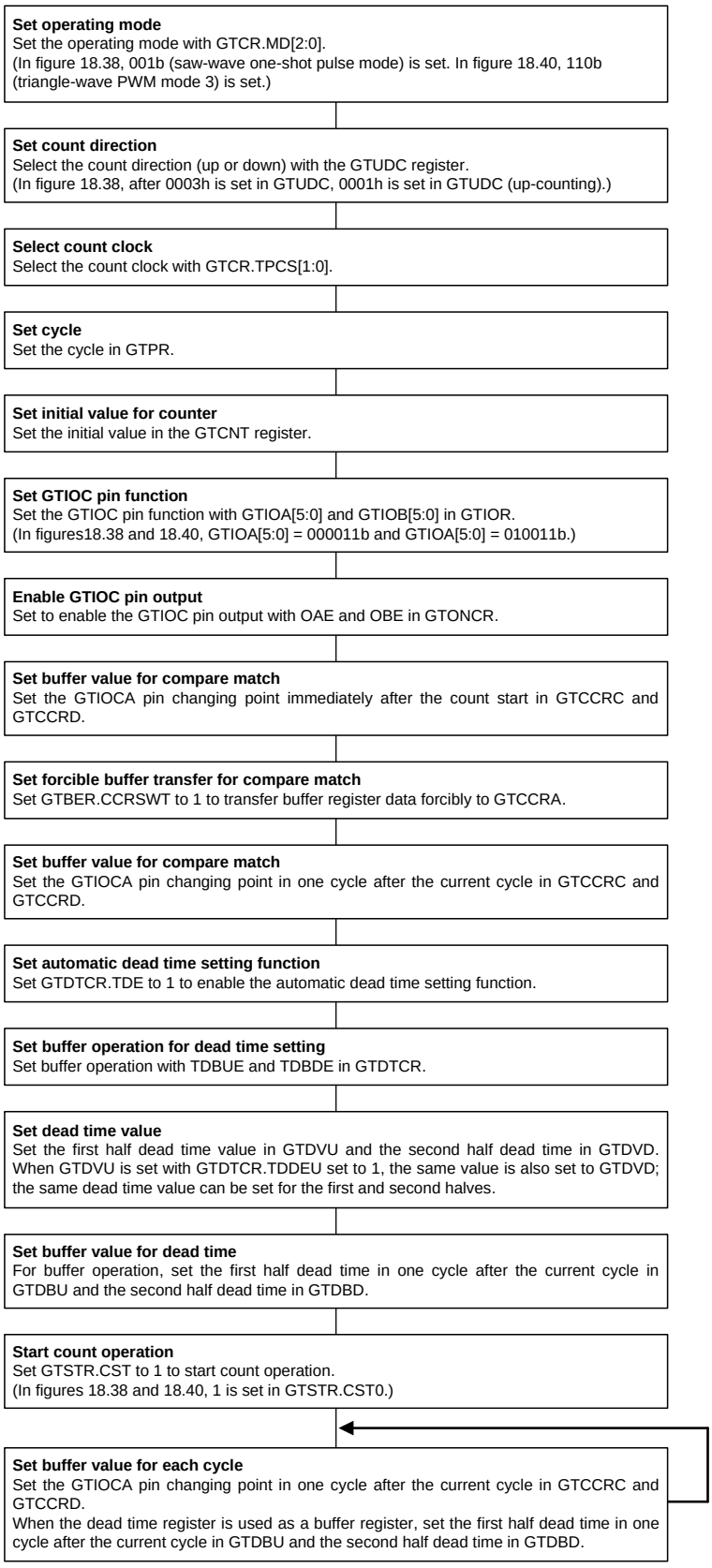


Figure 18.41 Example for Setting Automatic Dead Time Setting Function (Saw-Wave One-Shot Pulse Mode, Triangle-Wave PWM Mode 3)

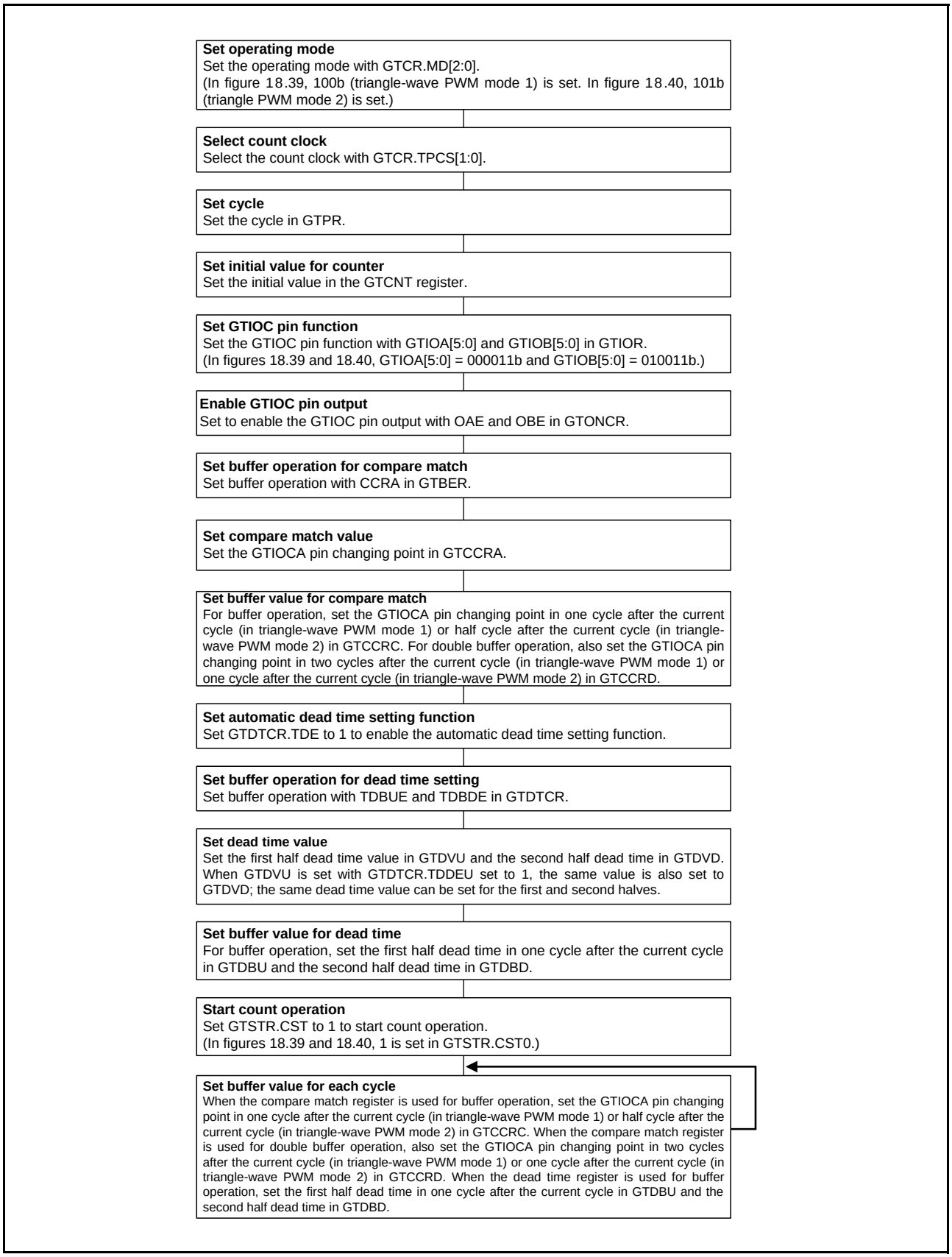


Figure 18.42 Example for Setting Automatic Dead Time Setting Function (Triangle-Wave PWM Mode 1 or 2)

18.3.5 Count Direction Changing Function

The count direction of the GTCNT counter can be changed by modifying the UD bit in GTUDC.
In saw-wave mode, if the UD bit in GTUDC is modified during count operation, the count direction is changed at an overflow (when modified during up-count operation) or an underflow (when modified during down-count operation). If the UD bit is modified while count operation is stopped and the UDF bit is 0, the UD bit modification is not reflected at the start of counting and the count direction is changed at an overflow or an underflow. If the UDF bit is set to 1 while count operation is stopped, the UD bit value at that time is reflected at the start of counting.
In triangle-wave mode, the count direction is not changed even though the UD bit in GTUDC is modified during count operation. Similarly, even though the UD bit is modified while count operation is stopped and UDF bit is 0, the UD bit value is not reflected to the count operation. If the UDF bit is set to 1 while count operation is stopped, the UD bit value at that time is reflected at the start of counting.
If the count direction is changed during saw-wave count operation, the GTPR value after the start of up-counting is reflected to the count cycle during up-count operation and the GTPR value before the start of down-counting is reflected during down-count operation.

Figure 18.43 shows an example of count direction changing function operation.

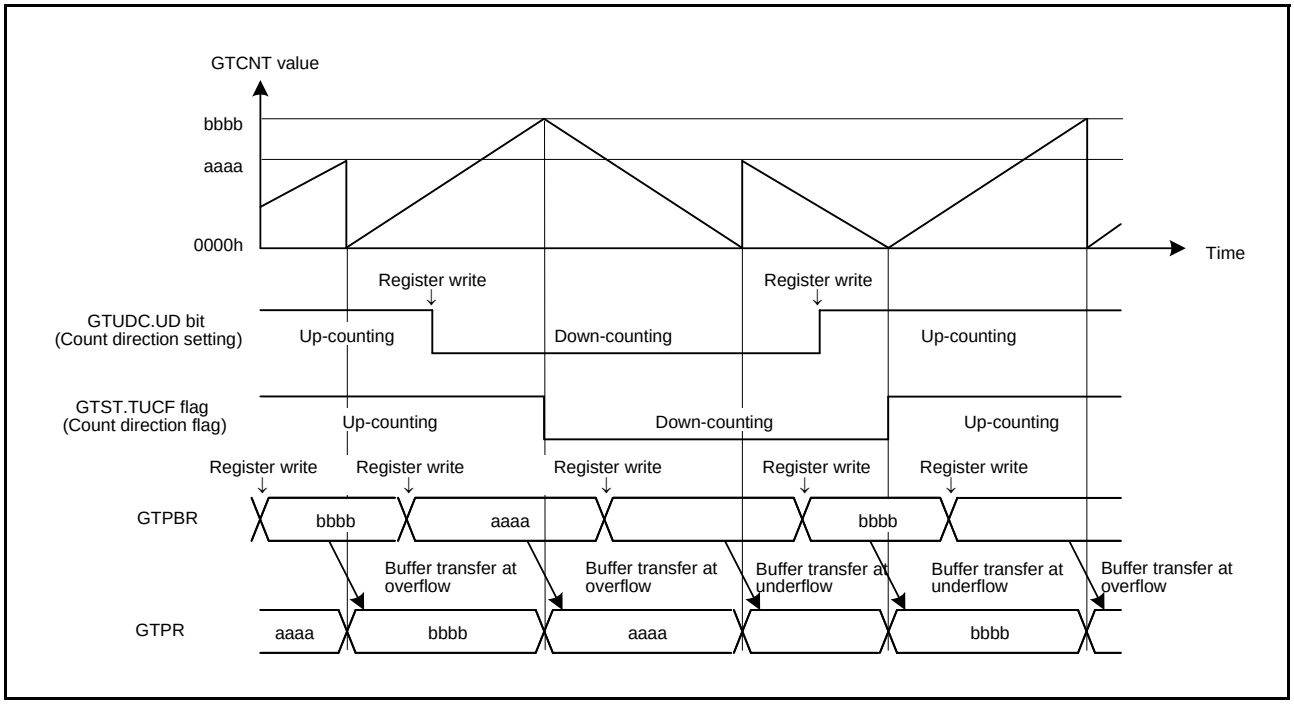


Figure 18.43 Example of Count Direction Changing Function Operation (during Buffer Operation)

18.3.6 Hardware Start/Stop and Clear Operation

The GTCNT counter can be started, stopped, or cleared by a hardware source in the RX62T. There are four hardware sources: GTETRG pin input, comparator detection, GTIOC3A/GTIOC3B pin input, and GTIOC3A/GTIOC3B internal output (output compare).
The counter can also be cleared by the GTCCRA or GTCCRB input capture.

18.3.6.1 Hardware Start Operation

The GTCNT counter can be started by a hardware source. Select a hardware source to start counting using GTHSSR.CSHSL, set the changing edge for the hardware source with GTHSCR.CSHW, and then enable to start counting.
Figure 18.44 shows an example of count start operation by a hardware source. Figure 18.45 shows the setting example.

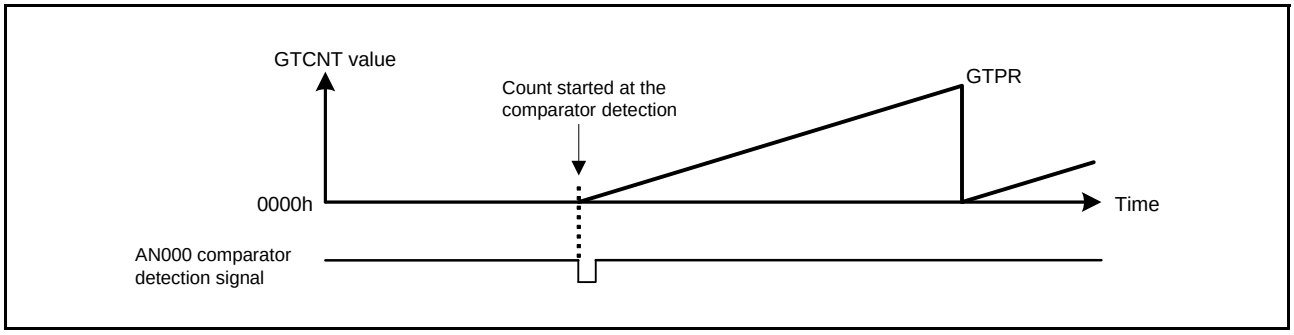


Figure 18.44 Example of Count Start Operation by Hardware Source (Started at AN000 Comparator Detection)

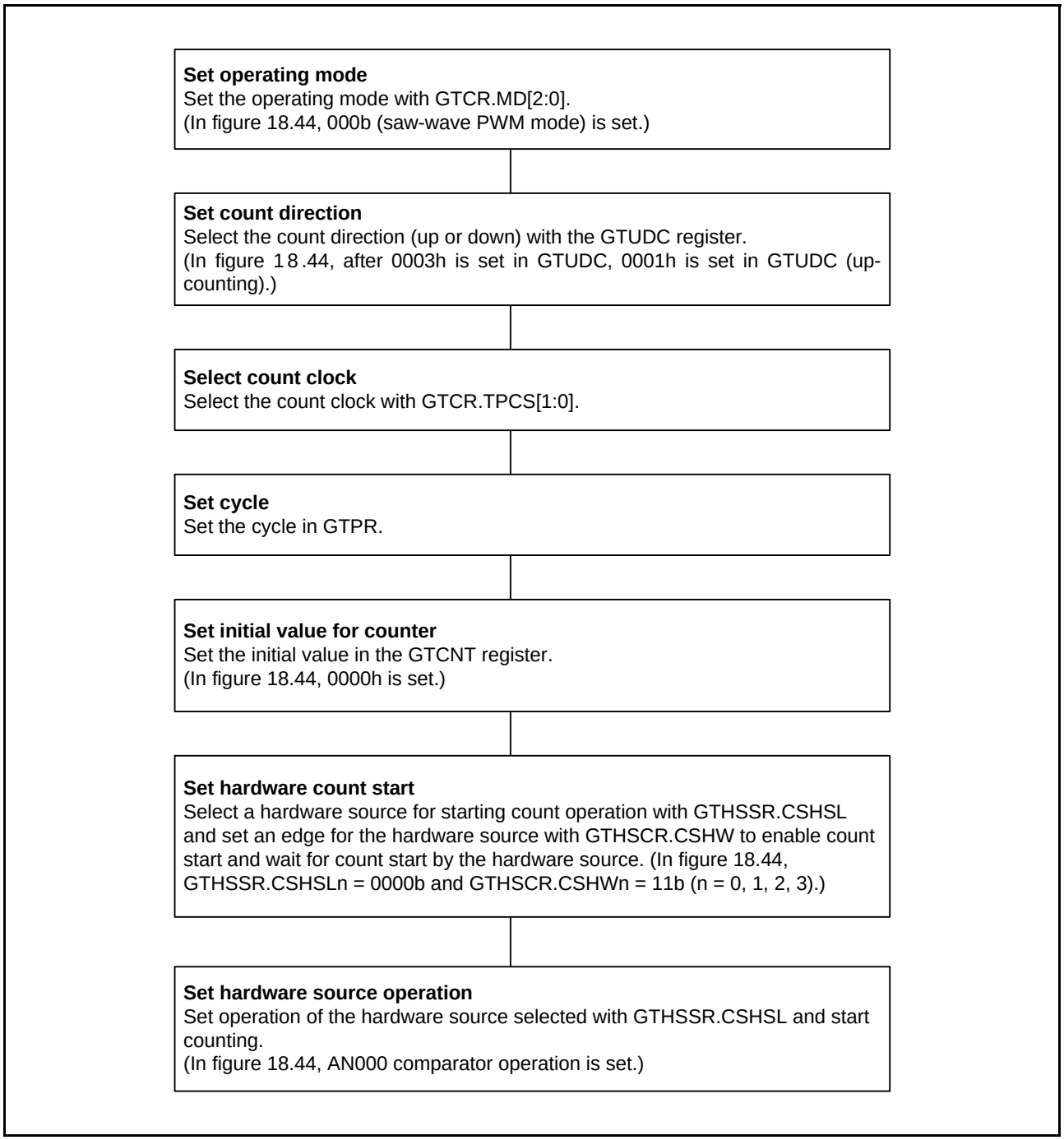


Figure 18.45 Example for Setting Count Start Operation by Hardware Source

18.3.6.2 Hardware Stop Operation

The GTCNT counter can be stopped by a hardware source. Select a hardware source to stop counting using GTHPSR.CSHPL, set the changing edge for the hardware source with GTHSCR.CPHW, and then enable to stop counting.

Figure 18.46 shows an example of count stop operation by a hardware source. Figure 18.47 shows the setting example. In this example, the count operation is stopped at both edges of the GTIOC3A internal output (output compare) and is restarted at both edges of the GTIOC3B internal output (output compare).

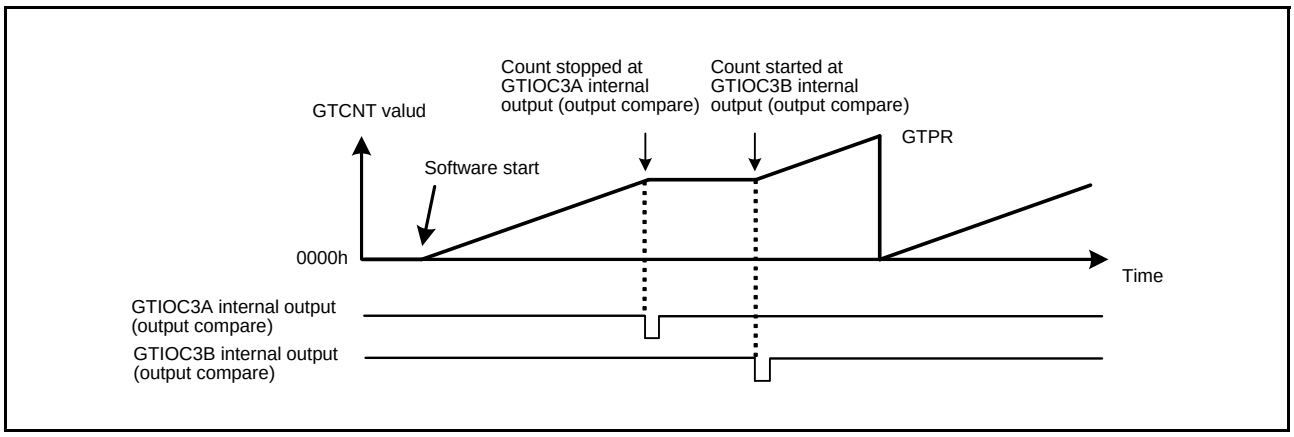


Figure 18.46 Example of Count Stop Operation by Hardware Source (Started by Software, Stopped at GTIOC3A Internal Output (Output Compare), Restarted at GTIOC3B Internal Output (Output Compare))

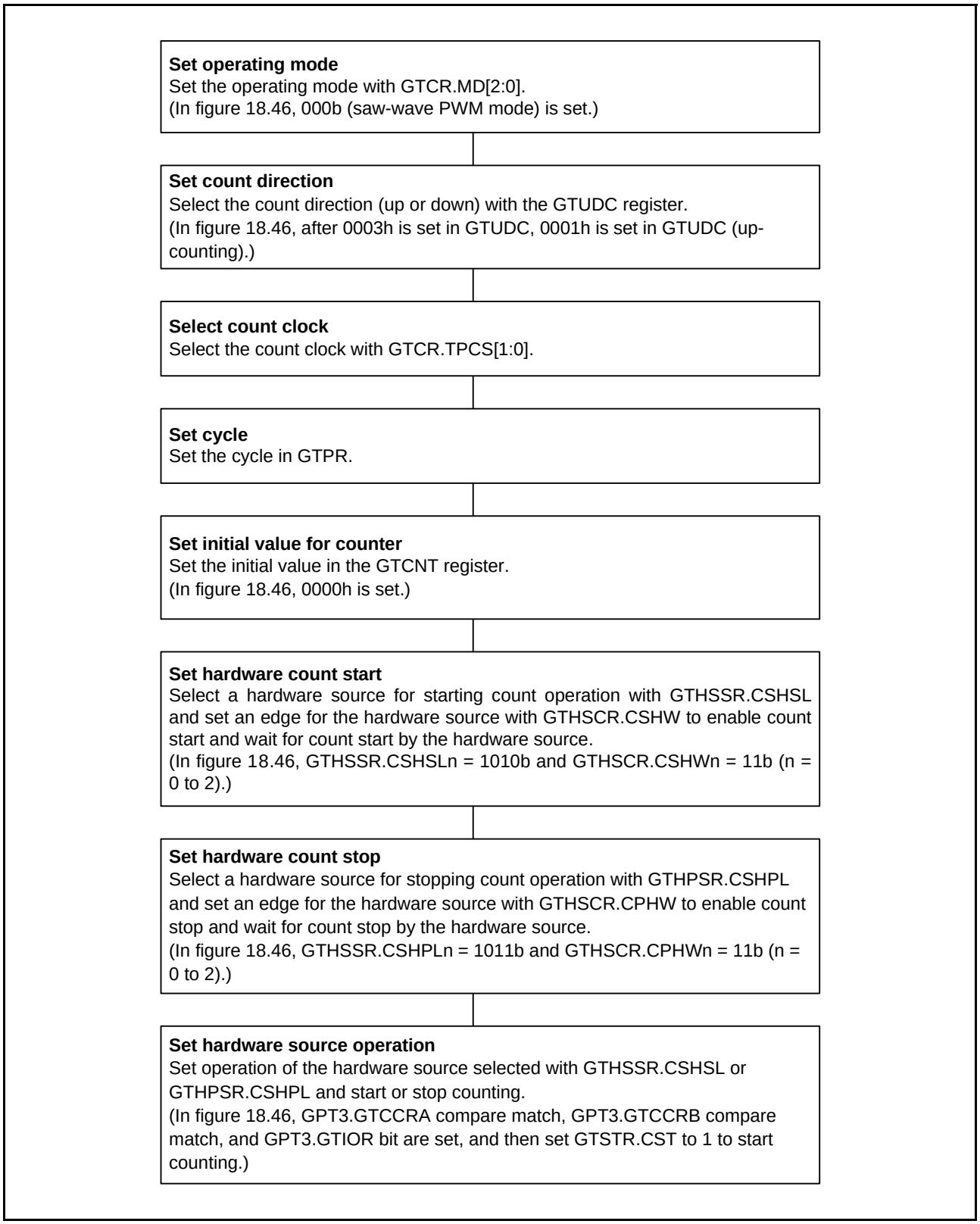


Figure 18.47 Example for Setting Count Stop Operation by Hardware Source

Figure 18.48 shows an example of count start/stop operation by a hardware source. Figure 18.49 shows the setting example. In this example, the counter operates during the high-level periods of the external trigger input GTETRG.

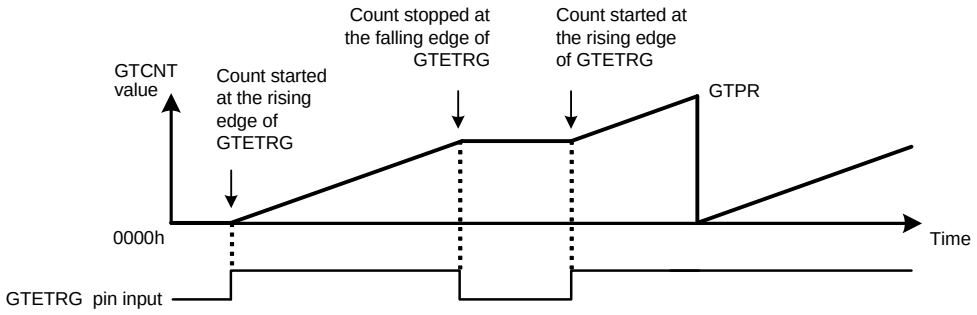


Figure 18.48 Example of Count Start/Stop Operation by Hardware Source (Started at Rising Edge of GTETRG Pin Input, Stopped at Falling Edge of GTETRG Pin Input)

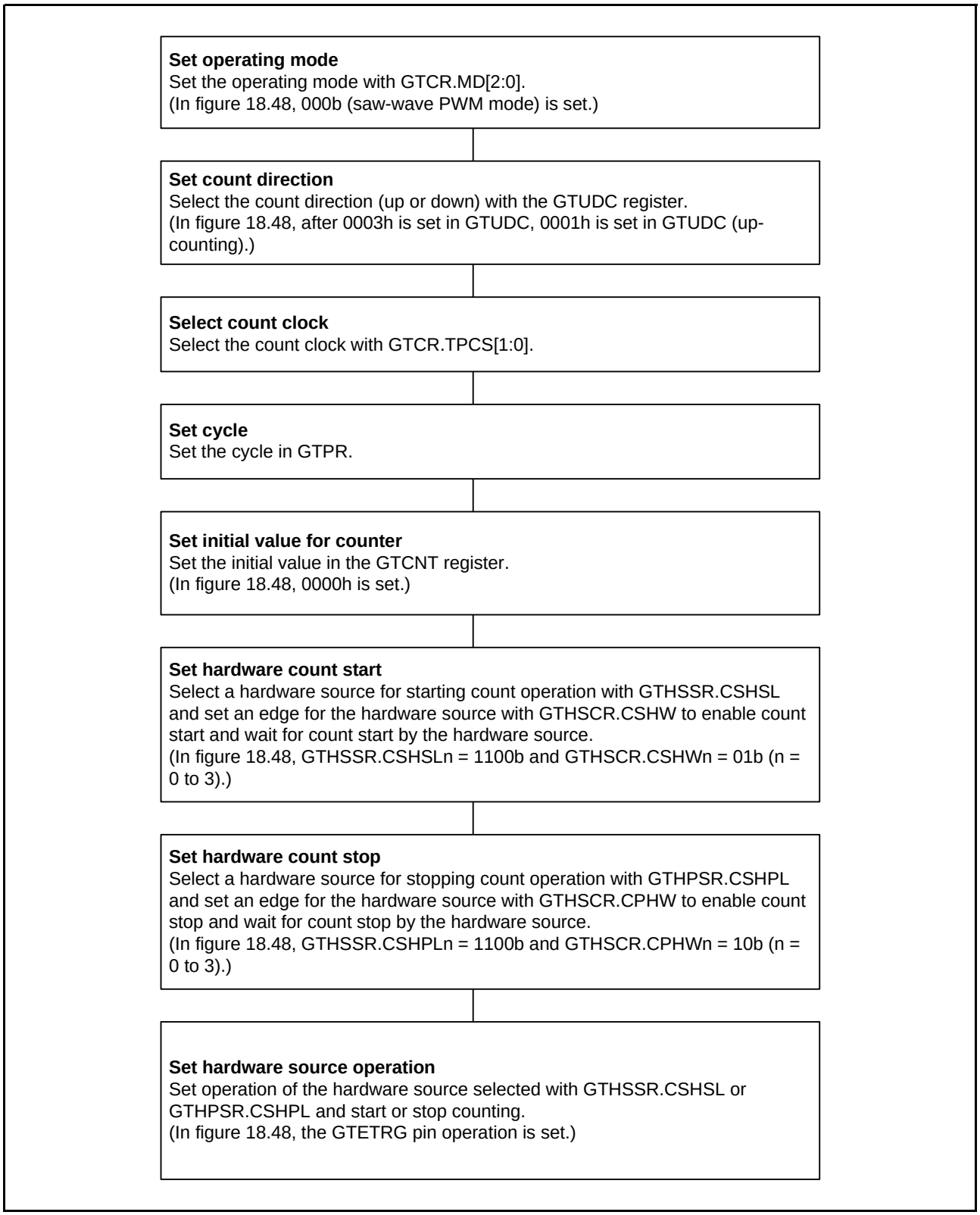


Figure 18.49 Example for Setting Count Start/Stop Operation by Hardware Source

18.3.6.3 Hardware Clear Operation

The GTCNT counter can be cleared by a hardware source. Select a hardware source to clear the counter using GTHPSR.CSHPL, set the changing edge for the hardware source with GTHCCR.CCHW, and then enable to clear the counter.

The counter can also be cleared by a GTCCRA or GTCCRB input capture by setting GTCR.CCLR[1:0].

Note that the GTCIV interrupt (overflow/underflow interrupt) is not generated when the counter is cleared by a hardware source or by software.

Figure 18.50 and Figure 18.51 show examples of counter clearing operation by a hardware source. Figure 18.52 shows the setting example. In this example, the counter is started at both edges of the GTIOC3A pin, and the counter is stopped/cleared at both edges of the GTOC3B pin input.

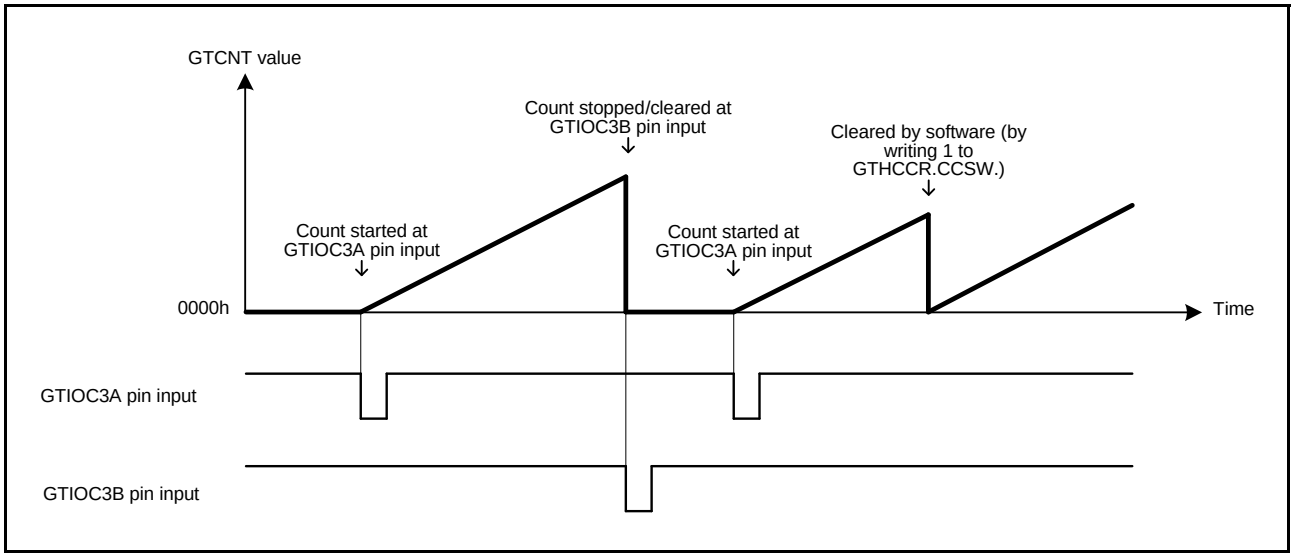


Figure 18.50 Examples of Count Clearing Operation by Hardware Source (Saw-Wave Up-Counting, Started at GTIOC3A Pin Input, Stopped/Cleared at GTIOC3B Pin Input)

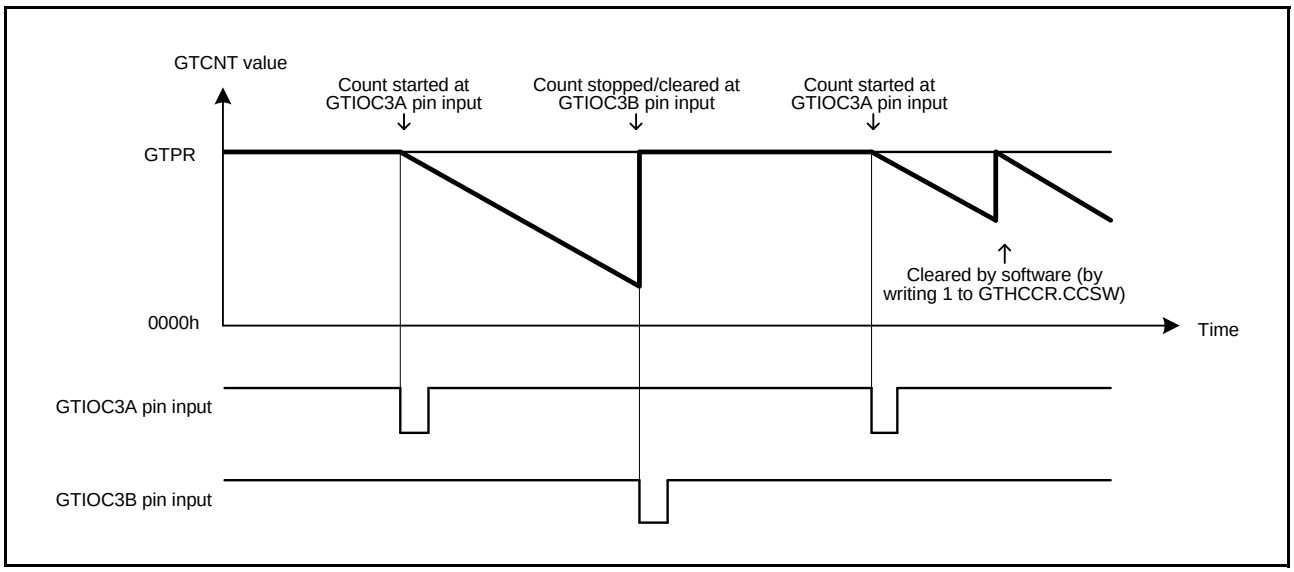


Figure 18.51 Examples of Count Clearing Operation by Hardware Source (Saw-Wave Down-Counting, Started at GTIOC3A Pin Input, Stopped/Cleared at GTIOC3B Pin Input)

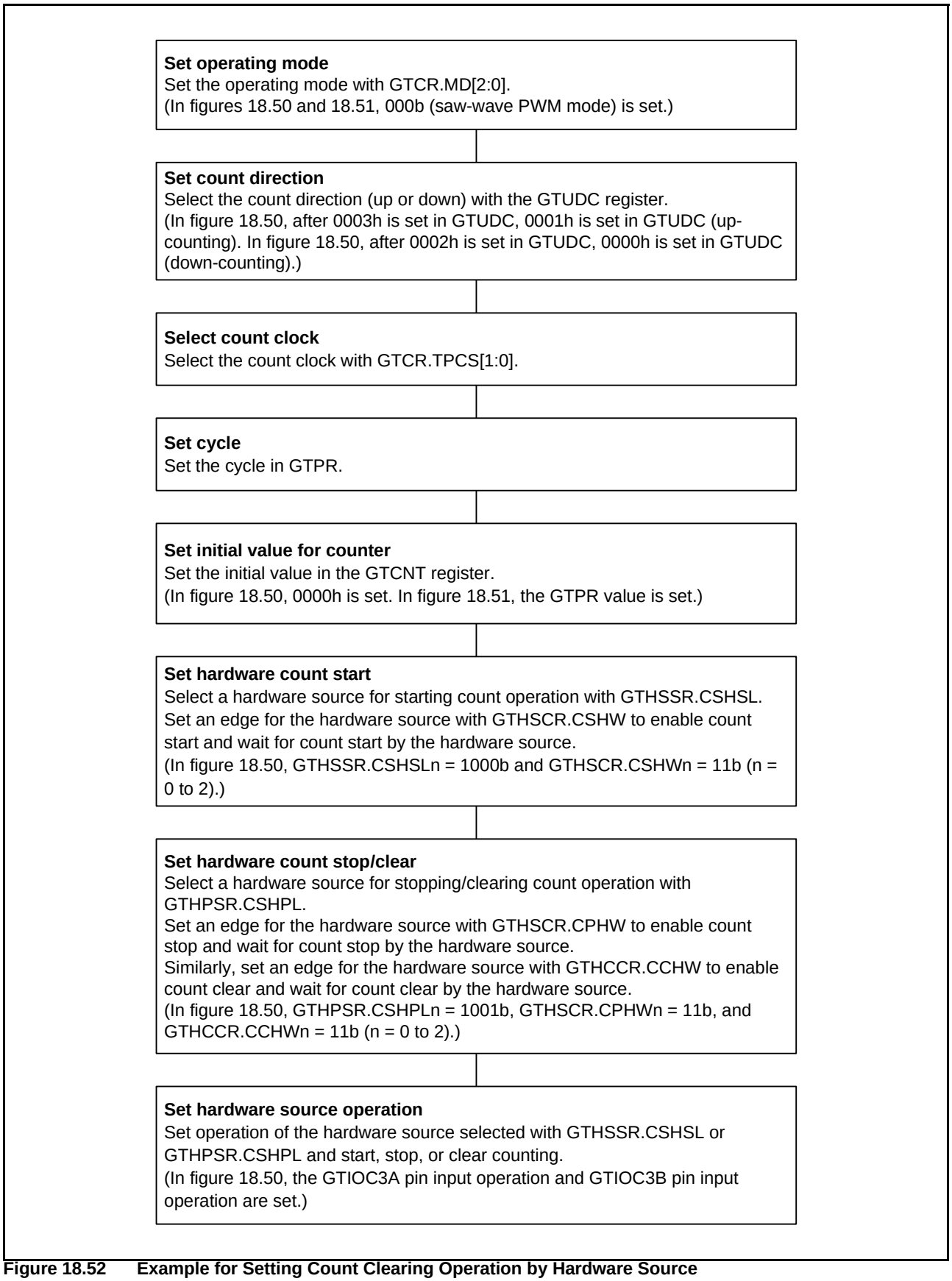


Figure 18.52 Example for Setting Count Clearing Operation by Hardware Source

The GTCIV interrupt (overflow/underflow interrupt) is not generated when the counter is cleared by a hardware source or by software.

Figure 18.53 shows the relationship between the counter clearing by a hardware source and the GTCIV interrupt.

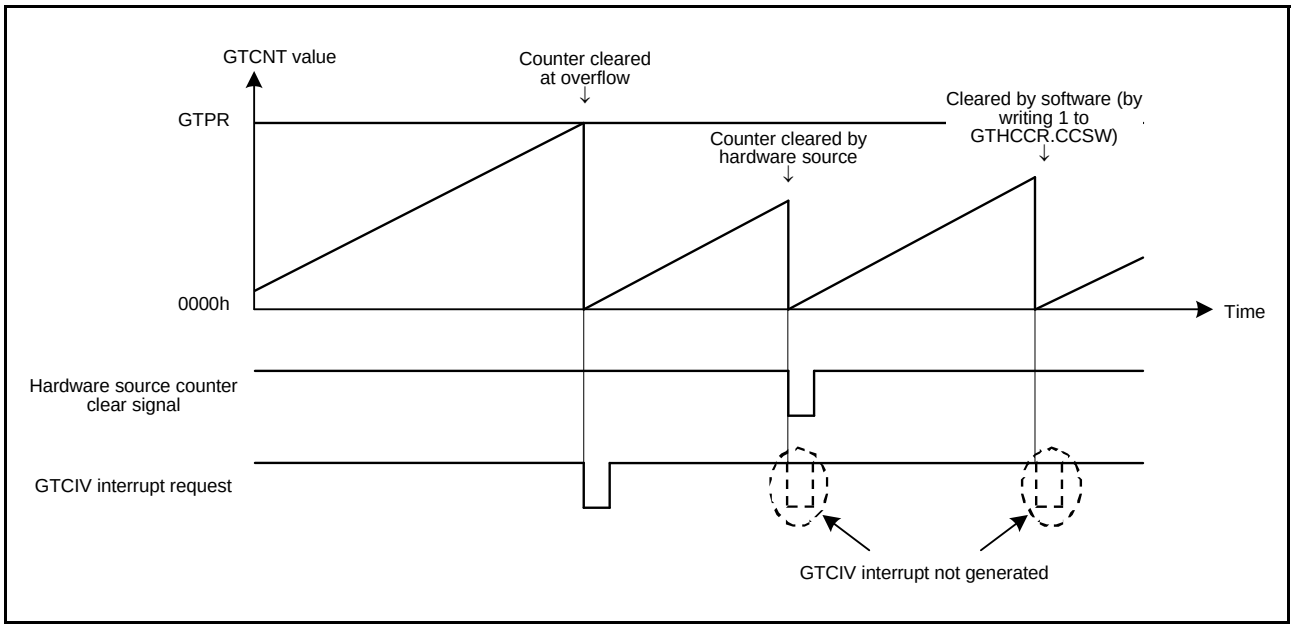


Figure 18.53 Relationship between Counter Clearing by Hardware Source and GTCIV Interrupt

18.3.7 Synchronized Operation

Synchronized operation on channels (synchronized clear operation, synchronized start operation) can be performed.

18.3.7.1 Synchronized Clear Operation

Synchronized clearing on channels can be controlled. Select which channels to be synchronously cleared by setting GTCR.CCLR[1:0] of the pertinent channels to 11b and which channel clearing source to be used for synchronized clearing by setting GTSYNC.SYNCn[1:0] (n = 0 to 3).

Figure 18.54 shows an example of synchronized clear operation, and Figure 18.56 shows the setting example. In this example, GPT1.GTCNT and GPT2.GTCNT are synchronously cleared by the GPT0.GTCNT clearing source (overflow).

Synchronized clearing of channels by a clear source does not cause synchronized clearing of another channel by the same clear source. (Synchronized clearing is not transmitted.)

Figure 18.55 shows an operation example in which two channels are synchronously cleared by the clear source of one of the channels and another channel is synchronously cleared by the clear source of the other one of the two channels.

Figure 18.56 shows the setting example. In this example, GPT1.GTCNT is synchronously cleared by GPT0.GTCNT clearing source (overflow), and GPT2.GTCNT is synchronously cleared by GPT1.GTCNT clearing source (overflow).

Although GPT1.GTCNT is synchronously cleared by the GPT0.GTCNT clearing source (overflow), GPT2.GTCNT is not synchronously cleared when GPT1.GTCNT is cleared by the GPT0.GTCNT clearing source.

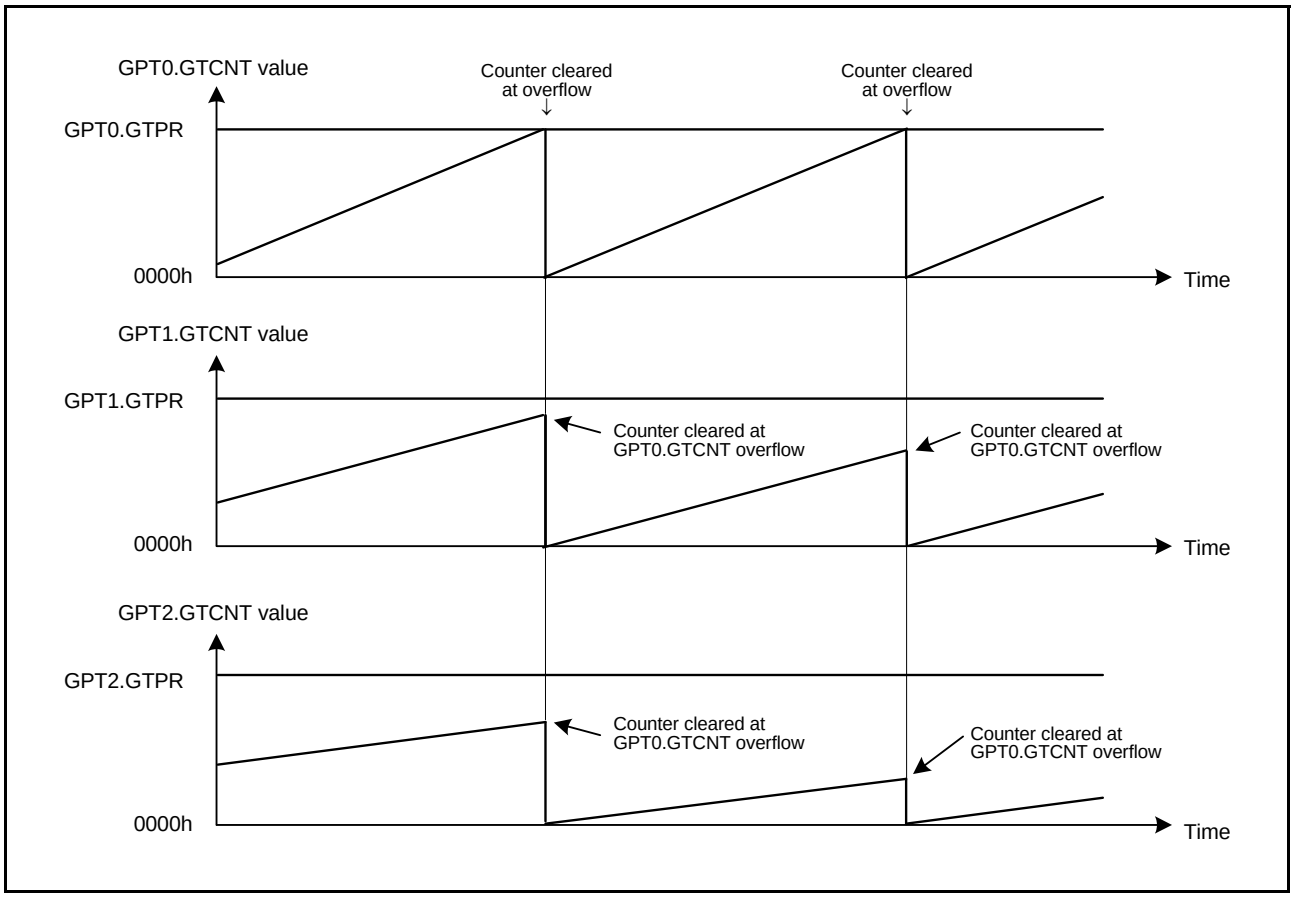


Figure 18.54 Example of Synchronized Clear Operation (GPT1.GTCNT and GPT2.GTCNT are Synchronously Cleared by GPT0.GTCNT Clearing Source)

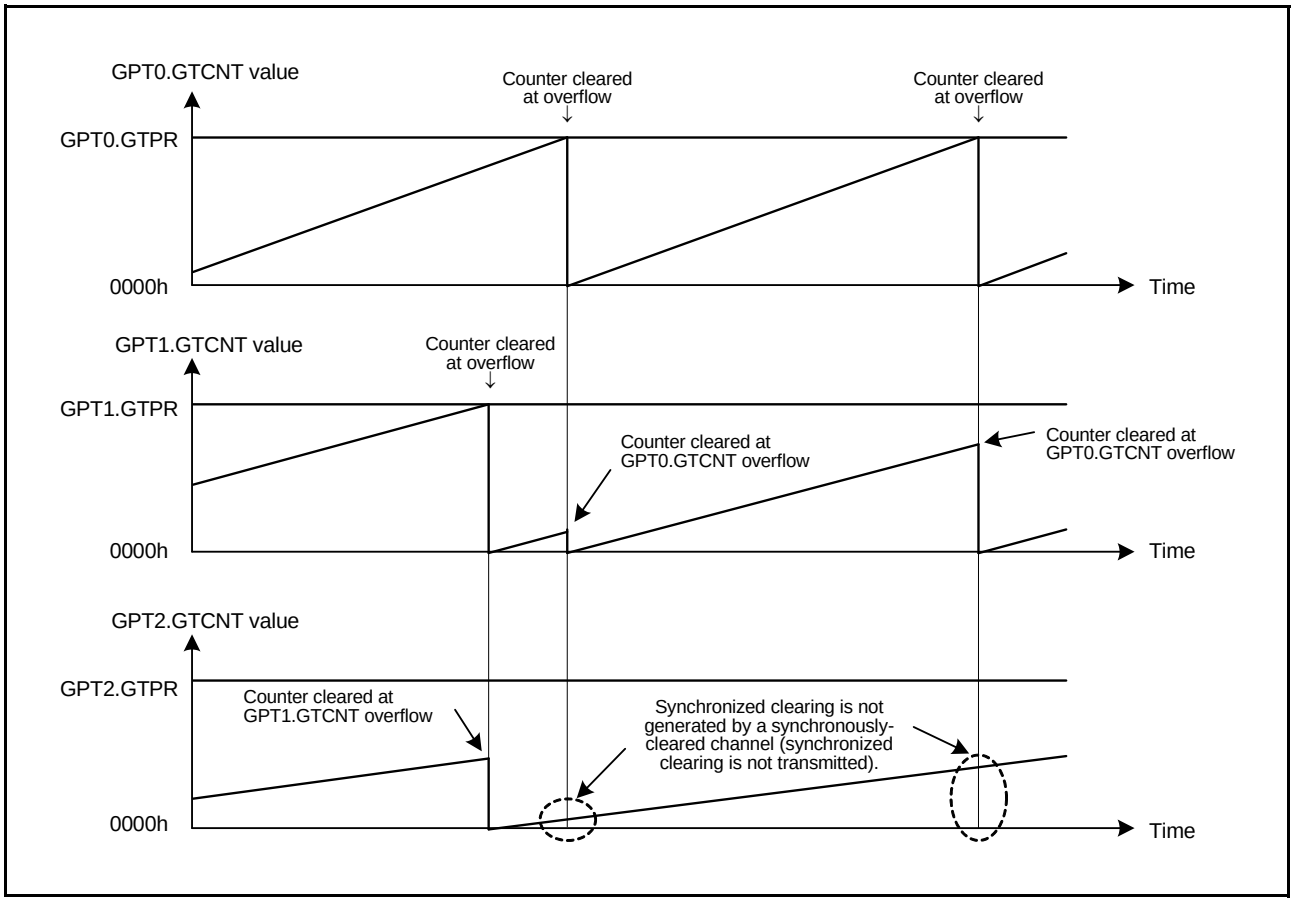


Figure 18.55 Example of Synchronized Clear Operation (GPT1.GTCNT is Synchronously Cleared by GPT0.GTCNT Clearing Source and GPT2.GTCNT is Synchronously Cleared by GPT1.GTCNT Clearing Source)

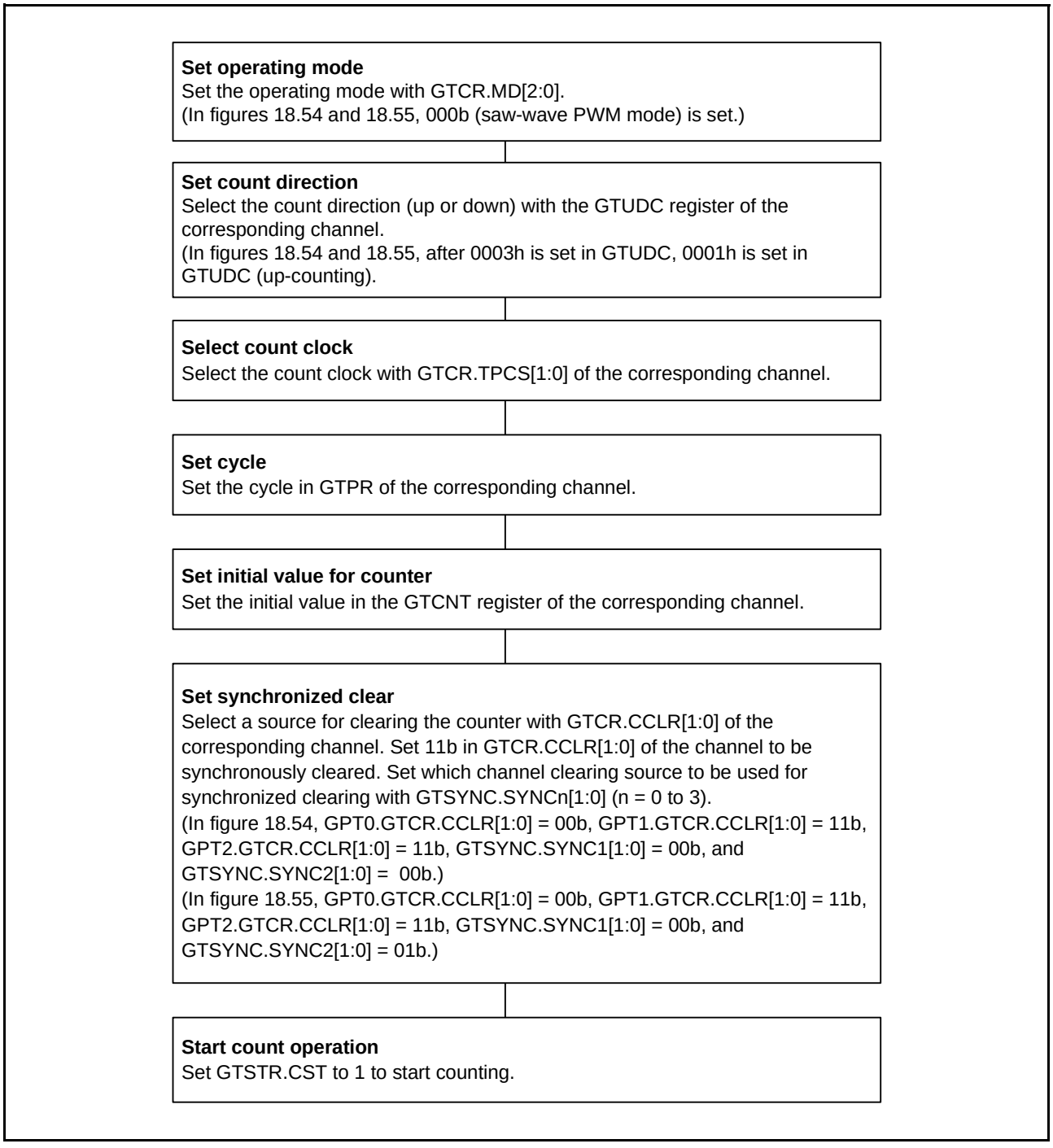


Figure 18.56 Example for Setting Synchronized Clear Operation

18.3.7.2 Synchronized Start Operation

(1) Simultaneous Start by Software

Count operation can be started simultaneously on channels by simultaneously setting the GTSTR.CST bits which correspond to the channels to be started simultaneously to 1. (n = 0 to 3)

Figure 18.57 shows an example of simultaneous start by software.

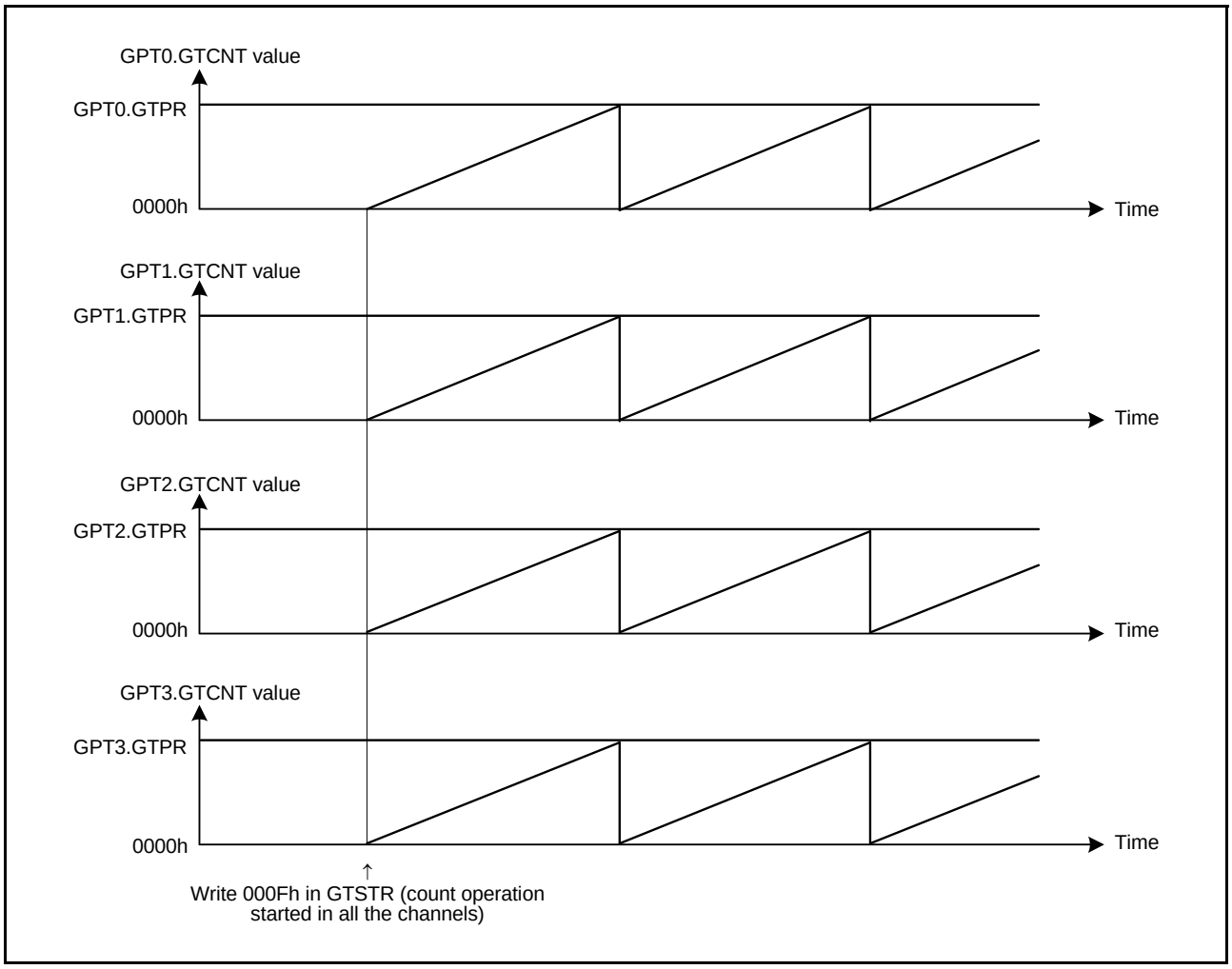


Figure 18.57 Example of Simultaneous Start by Software (with Same Count Cycle (GTPR Value))

(2) Phase Start by Software

Count start with a phase difference is possible by setting the initial value in GCNT before counting starts and then simultaneously setting the CST bits in GTSTR which correspond to the channels to be started simultaneously to 1. (n = 0 to 3)

Figure 18.58 shows an example of phase start operation by software.

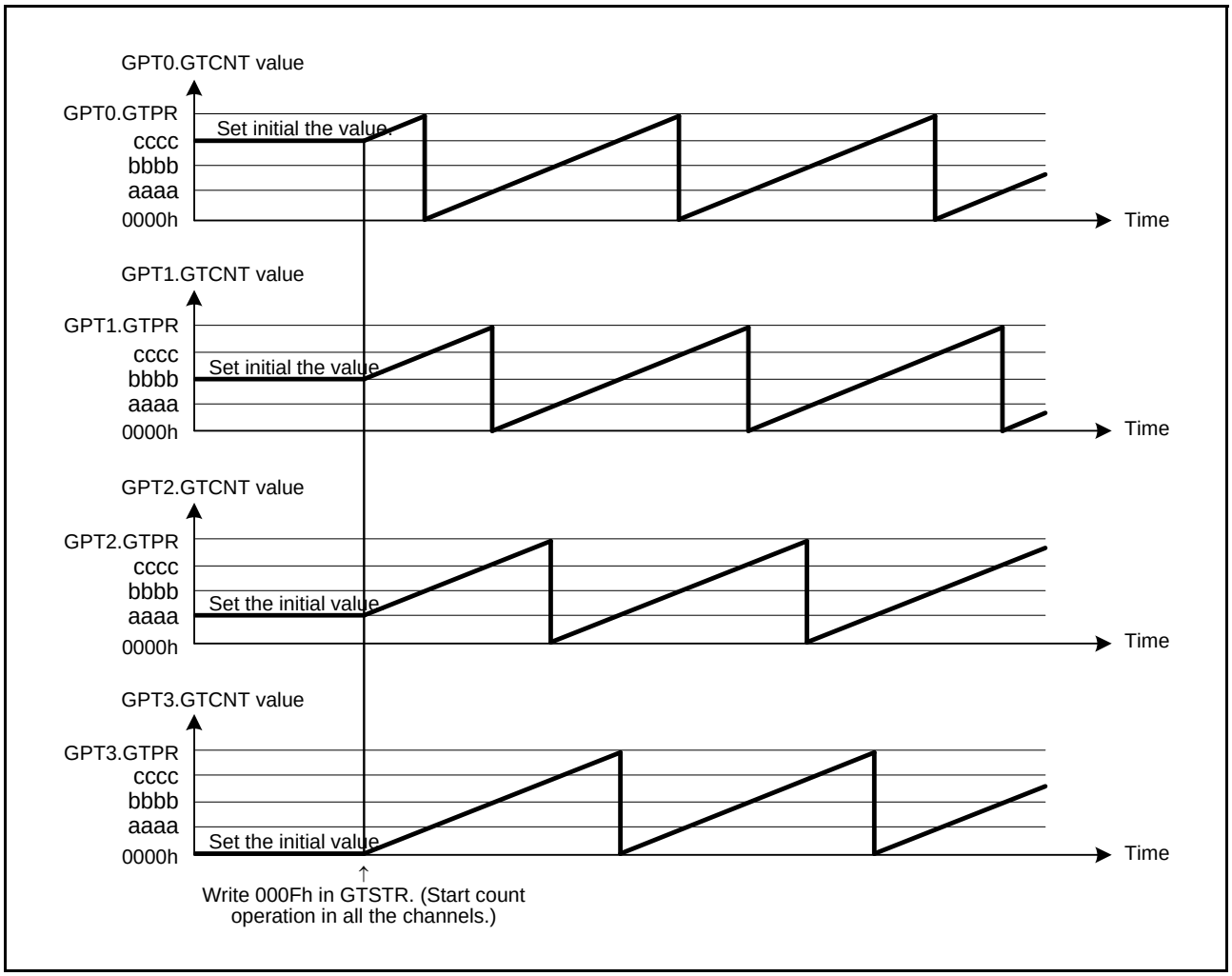


Figure 18.58 Example of Software Phase Start (with Same Count Cycle (GTPR Value))

(3) Simultaneous Start by Hardware Source

Count operation can be started simultaneously on channels by a hardware source in the RX62T. There are four hardware sources: GTETRG pin input, comparator detection, GTIOC3A/GTIOC3B pin input, and GTIOC3A/GTIOC3B internal output (output compare).

Figure 18.59 shows an example of simultaneous start operation by a hardware source and Figure 18.60 shows the setting example. In this example, count operation is started in all the channels by the AN000 comparator detection.

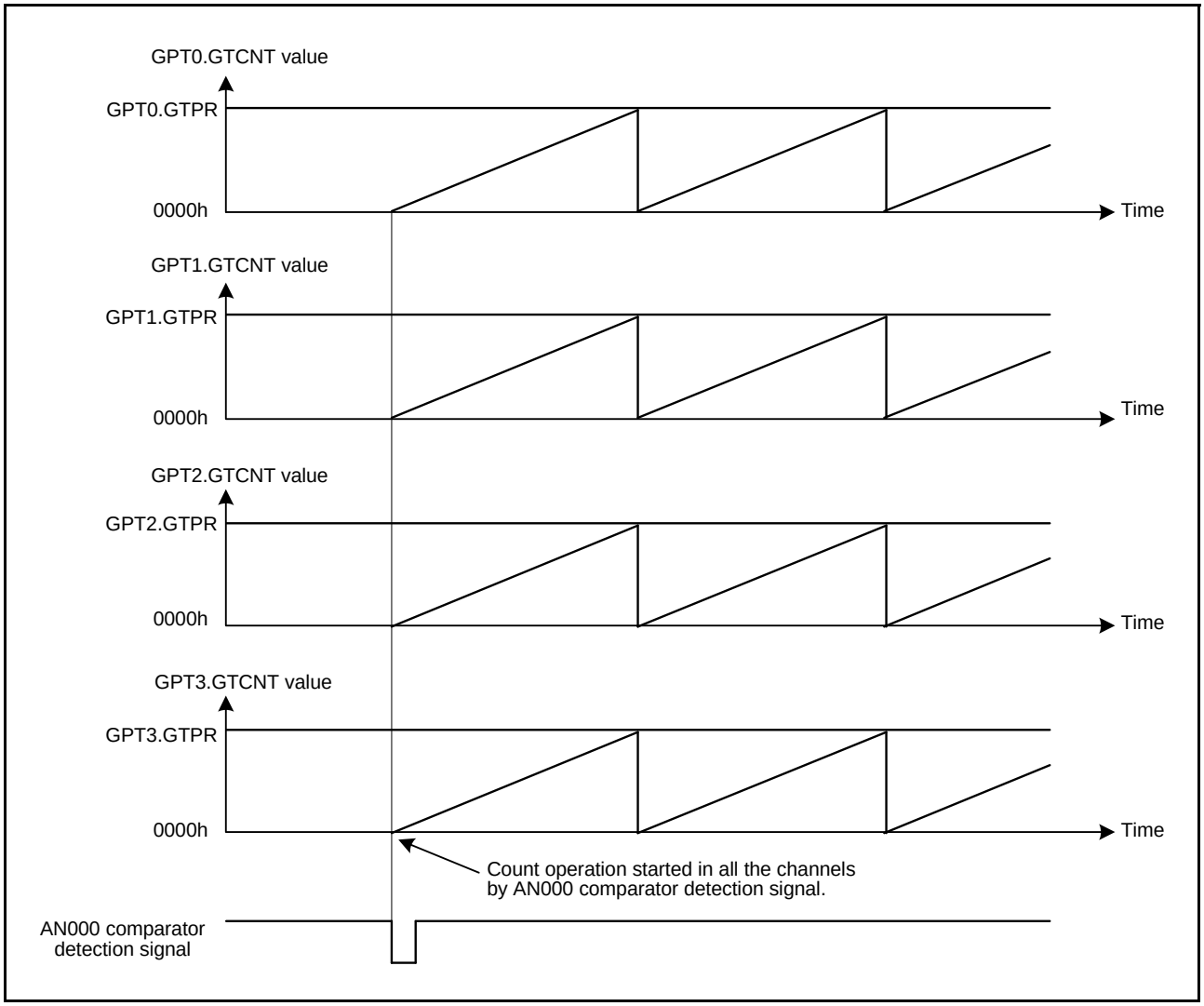


Figure 18.59 Example of Simultaneous Start Operation by Hardware Source (with Same Count Cycle (GTPR Value))

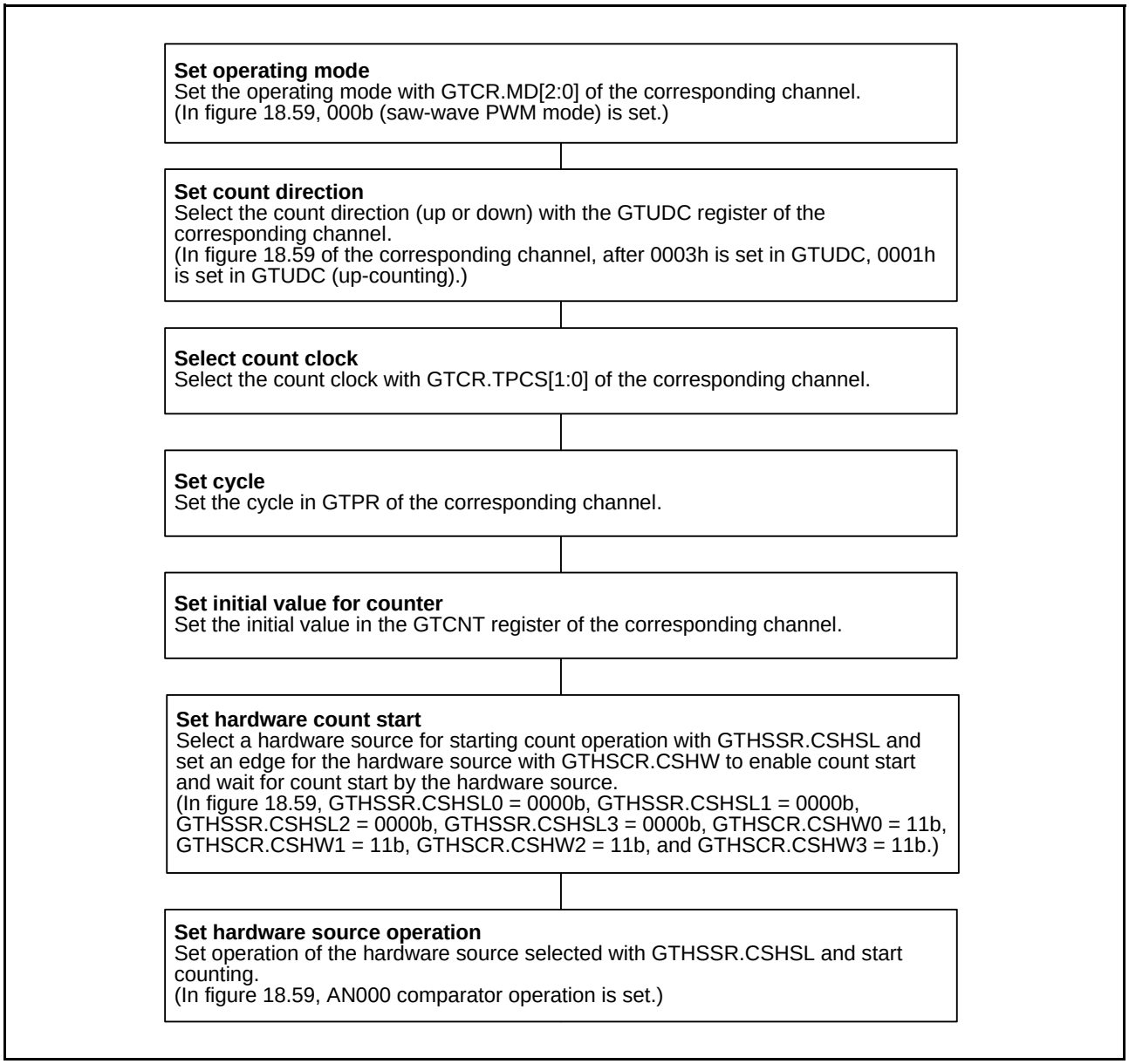


Figure 18.60 Example for Setting Simultaneous Start by Hardware Source

(4) Phase Start by Hardware Source

Count start with a phase difference is possible by a hardware source in the RX62T.
There are four hardware sources: GTETRG pin input, comparator detection, GTIOC3A/GTIOC3B pin input, and GTIOC3A/GTIOC3B internal output (output compare).
Figure 18.61 shows an example of phase start operation by a hardware source and Figure 18.62 shows the setting example. In this example, GPT3.GTCNT and GPT0.GTCNT simultaneously start counting and GPT1.GTCNT and GPT2.GTCNT start counting by the GTIOC3A and GTIOC3B internal outputs (output compare).

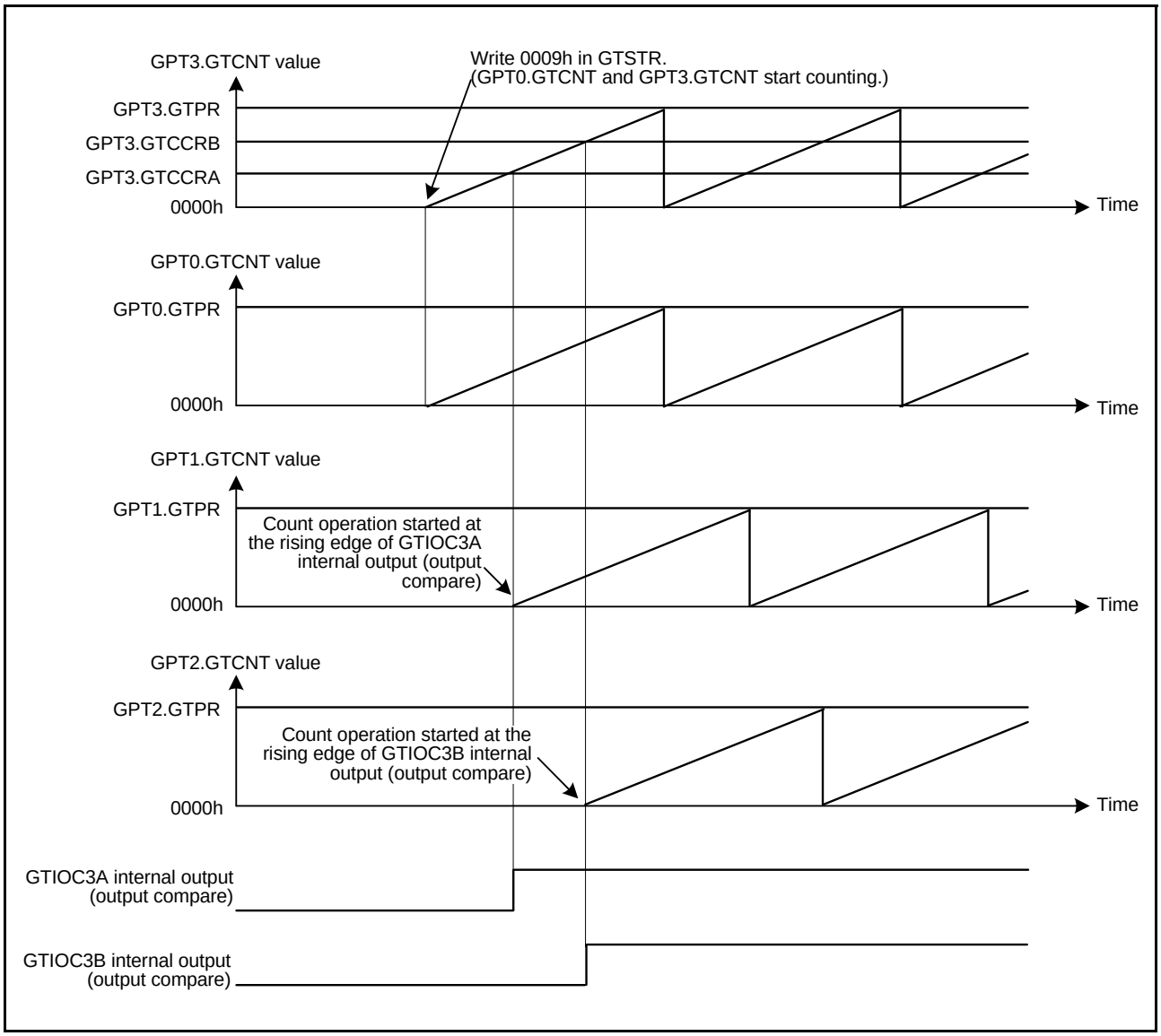


Figure 18.61 Example of Phase Start Operation by Hardware Source (with Same Count Cycle (GTPR Value))

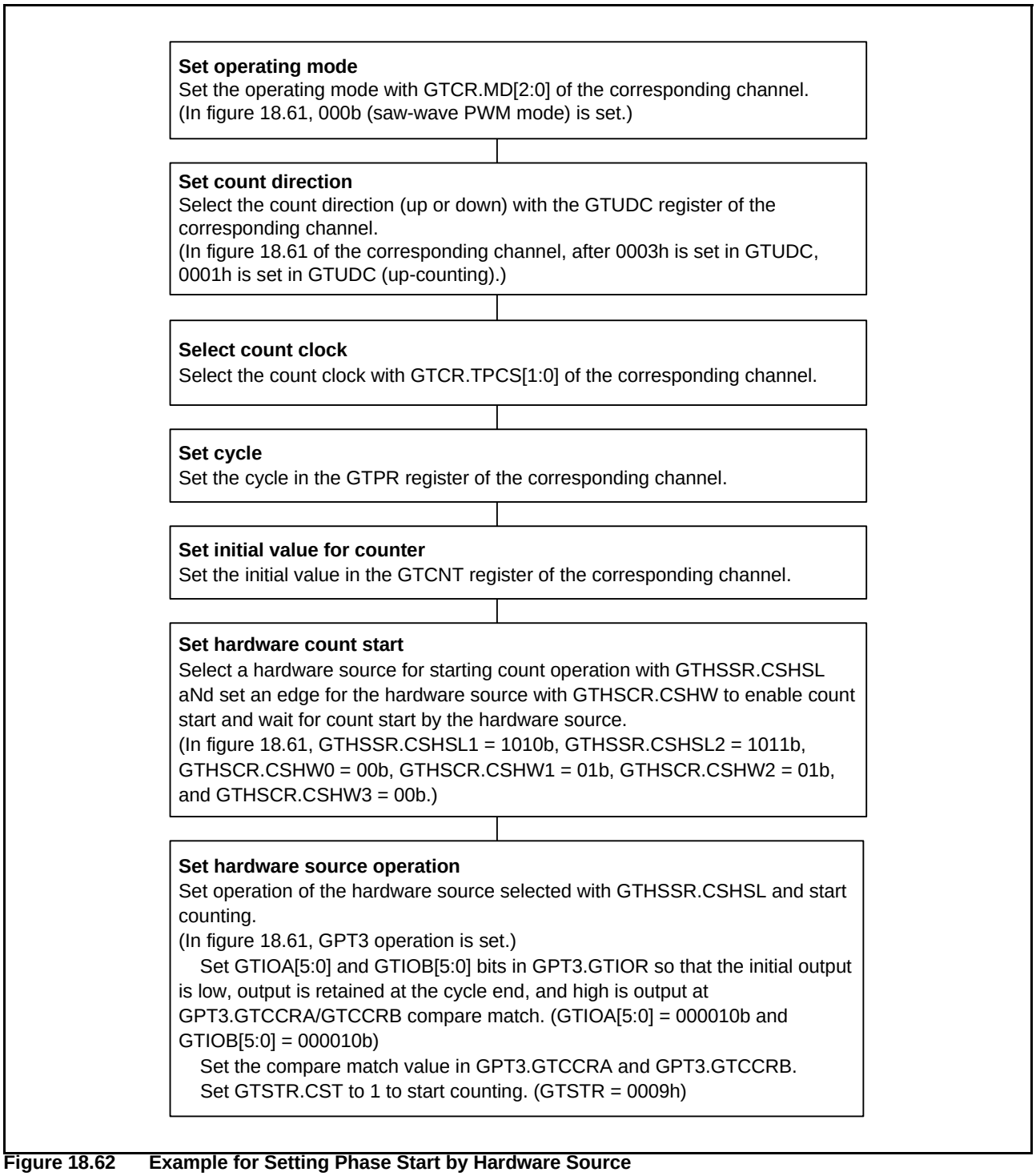


Figure 18.62 Example for Setting Phase Start by Hardware Source

18.3.8 PWM Output Operation Examples

(1) Synchronized PWM Output

The GPT can output eight phases of linked PWM waveforms for a maximum of four channels by synchronizing operation of the channels.

Figure 18.63 shows an example in which all the channels perform synchronized operation in saw-wave PWM mode and eight phases of PWM waveforms are output. The GTIOCnA is set so that it will output low as the initial value, high at a GTCCRA compare match, and low at the cycle end. The GTIOCnB is set so that it will output low as the initial value, high at a GTCCRB compare match, and low at the cycle end.

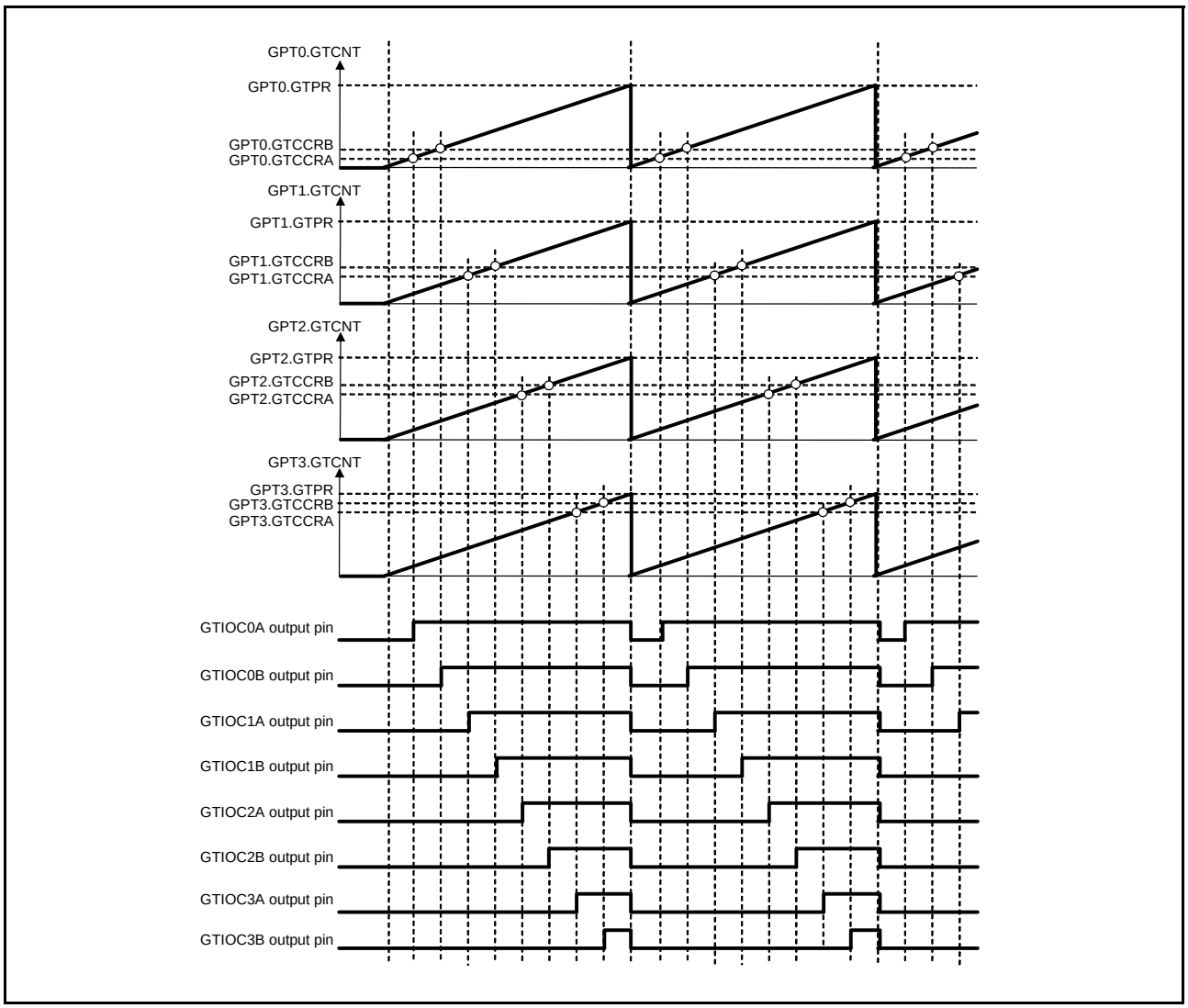


Figure 18.63 Example of Synchronized PWM Output

(2) Three-Phase Saw-Wave Complementary PWM Output

Figure 18.64 shows an example in which three channels perform synchronized operation in saw-wave PWM mode and three-phase complementary PWM waveforms are output. The GTIOCnA is set so that it will output low as the initial value, high at a GTCCRA compare match, and low at the cycle end. The GTIOCnB is set so that it will output high as the initial value, low at a GTCCRB compare match, and high at the cycle end.

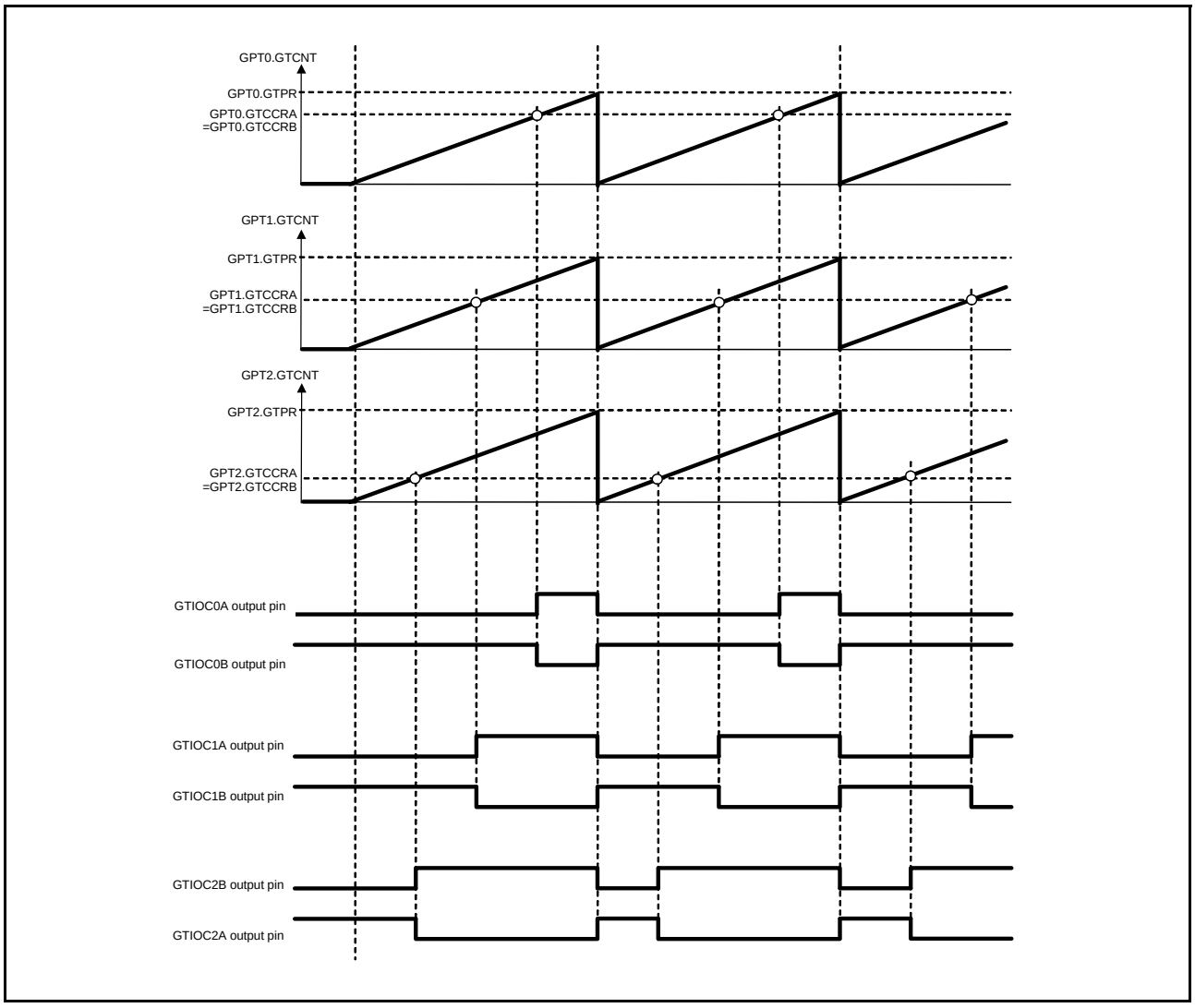


Figure 18.64 Example of Three-Phase Saw-Wave Complementary PWM Output

(3) Three-Phase Saw-Wave Complementary PWM Output with Automatic Dead Time Setting

Figure 18.65 shows an example in which three channels perform synchronized operation in saw-wave one-shot pulse mode with automatic dead time setting and three-phase complementary PWM waveforms are output. The GTIOCnA is set so that it will output low as the initial value, toggle the output at a GTCCRA compare match, and retain the output at the cycle end. The GTIOCnB is set so that it will output high as the initial value, toggle the output at a GTCCRB compare match, and retain the output at the cycle end.

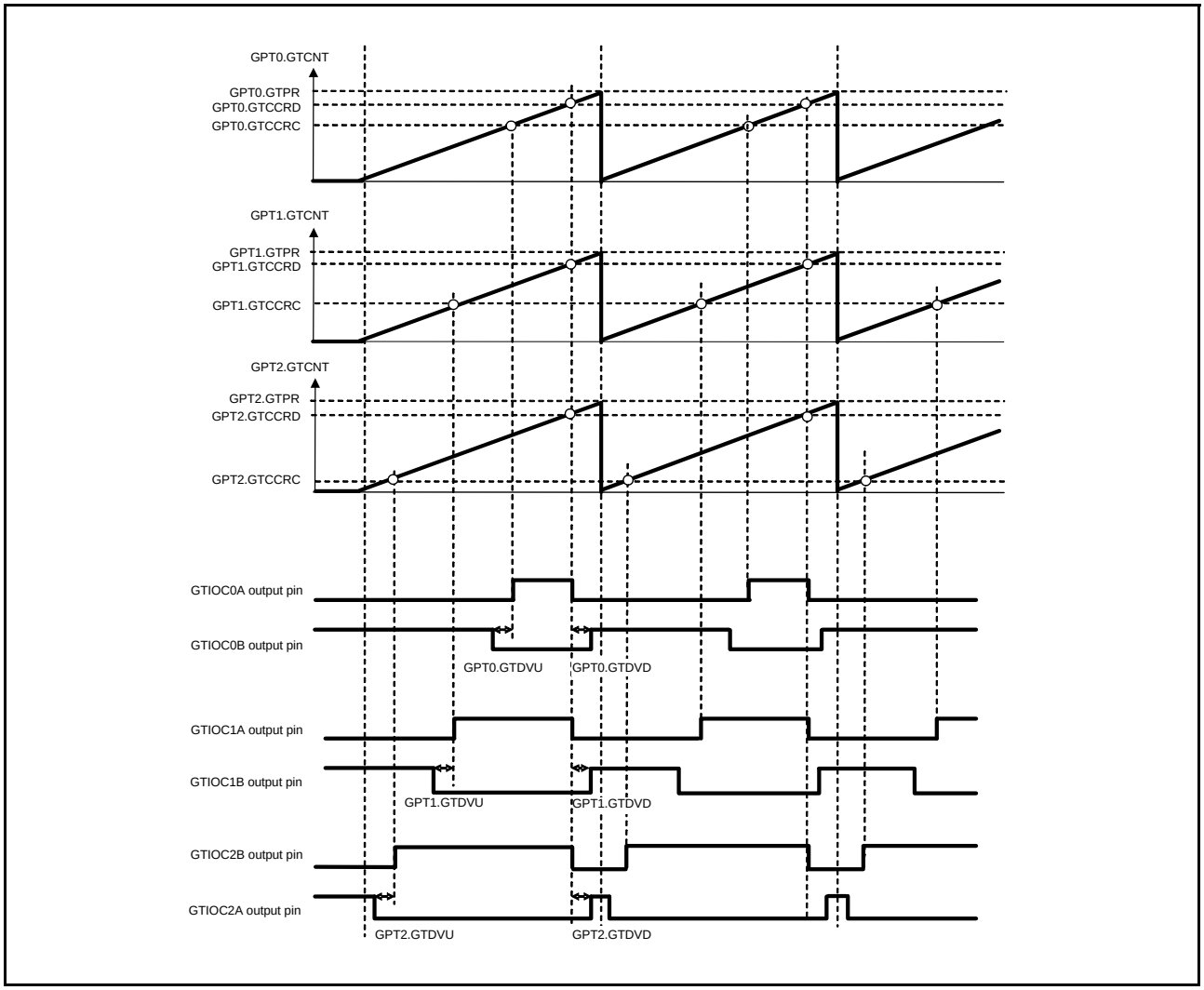


Figure 18.65 Example of Three-Phase Saw-Wave Complementary PWM Output with Automatic Dead Time Setting

(4) Three-Phase Triangle-Wave Complementary PWM Output

Figure 18.66 shows an example in which three channels perform synchronized operation in triangle-wave PWM mode 1 and three-phase complementary PWM waveforms are output. The GTIOCnA is set so that it will output low as the initial value, toggle the output at a GTCCRA compare match, and retain the output at the cycle end. The GTIOCnB is set so that it will output high as the initial value, toggle the output at a GTCCRB compare match, and retain the output at the cycle end.

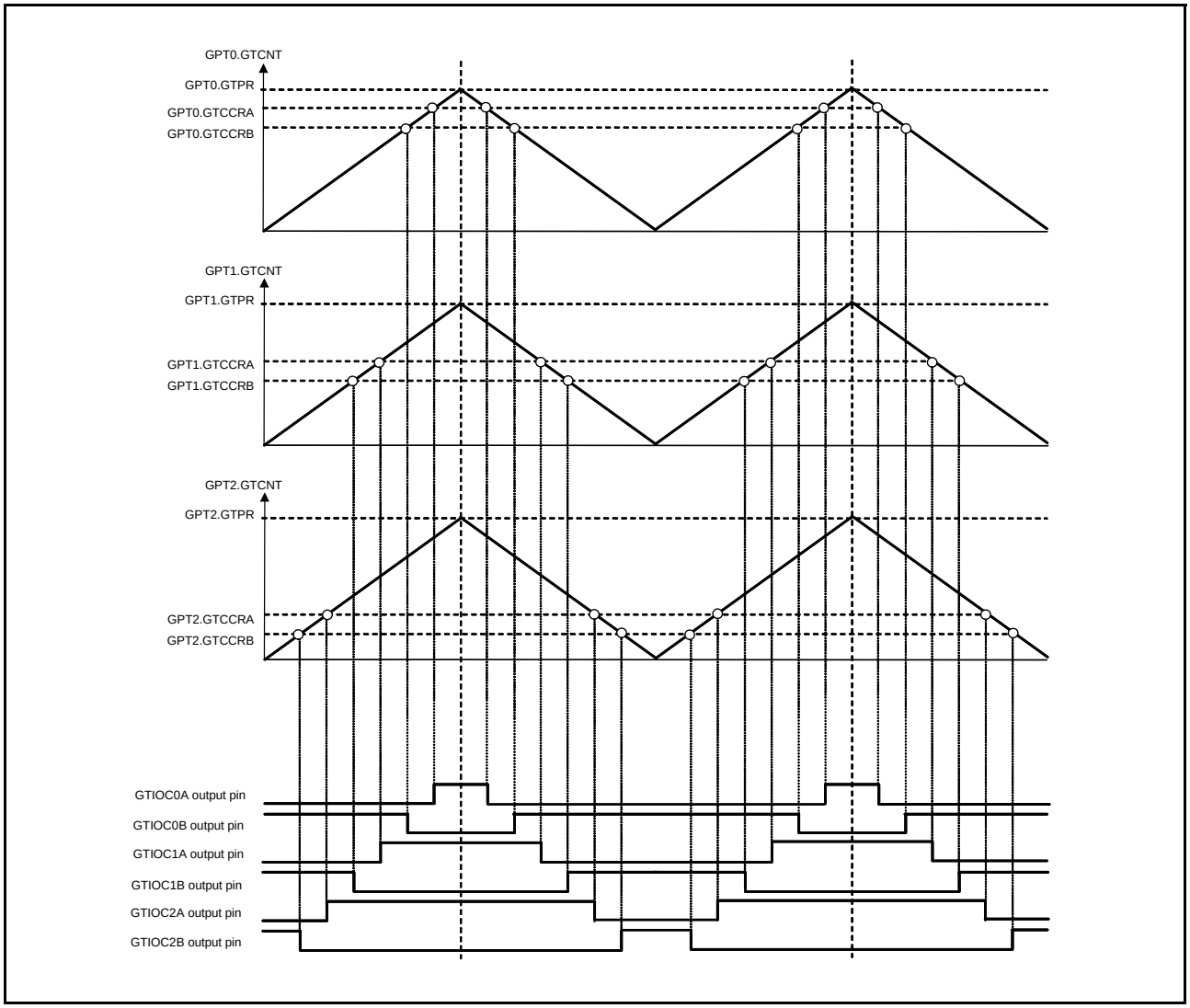


Figure 18.66 Example of Three-Phase Triangle-Wave Complementary PWM Output

(5) Three-Phase Triangle-Wave Complementary PWM Output with Automatic Dead Time Setting

Figure 18.67 shows an example in which three channels perform synchronized operation in triangle-wave PWM mode 1 with automatic dead time setting and three-phase complementary PWM waveforms are output. The GTIOCnA is set so that it will output low as the initial value, toggle the output at a GTCCRA compare match, and retain the output at the cycle end. The GTIOCnB is set so that it will output high as the initial value, toggle the output at a GTCCRB compare match, and retain the output at the cycle end.

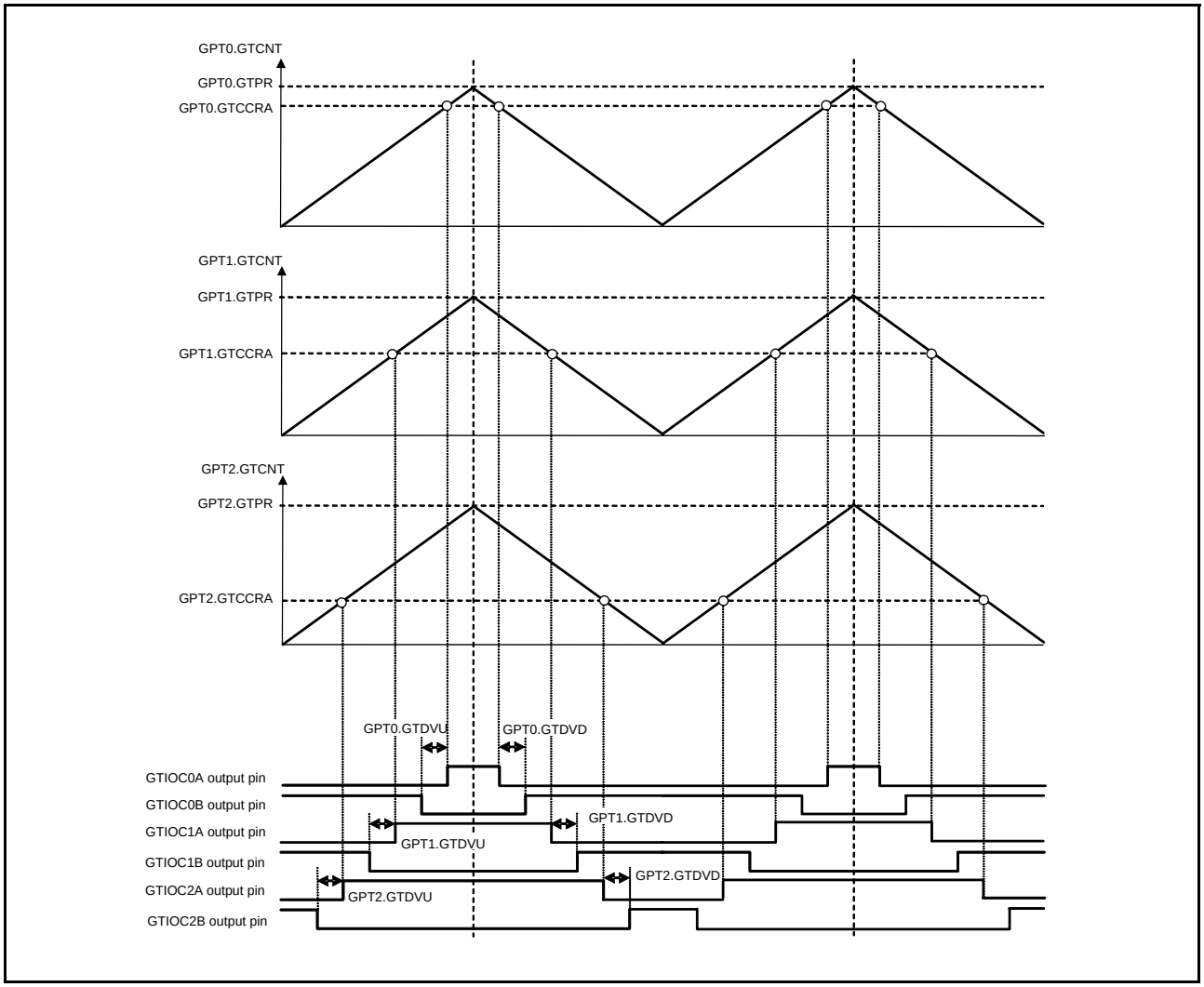


Figure 18.67 Example of Three-Phase Triangle-Wave Complementary PWM Output with Automatic Dead Time Setting

(6) Three-Phase Asymmetric Triangle-Wave Complementary PWM Output with Automatic Dead Time Setting

Figure 18.68 shows an example in which three channels perform synchronized operation in triangle-wave PWM mode 3 with automatic dead time setting and three-phase complementary PWM waveforms are output. The GTIOCnA is set so that it will output low as the initial value, toggle the output at a GTCCRA compare match, and retain the output at the cycle end. The GTIOCnB is set so that it will output high as the initial value, toggle the output at a GTCCRB compare match, and retain the output at the cycle end.

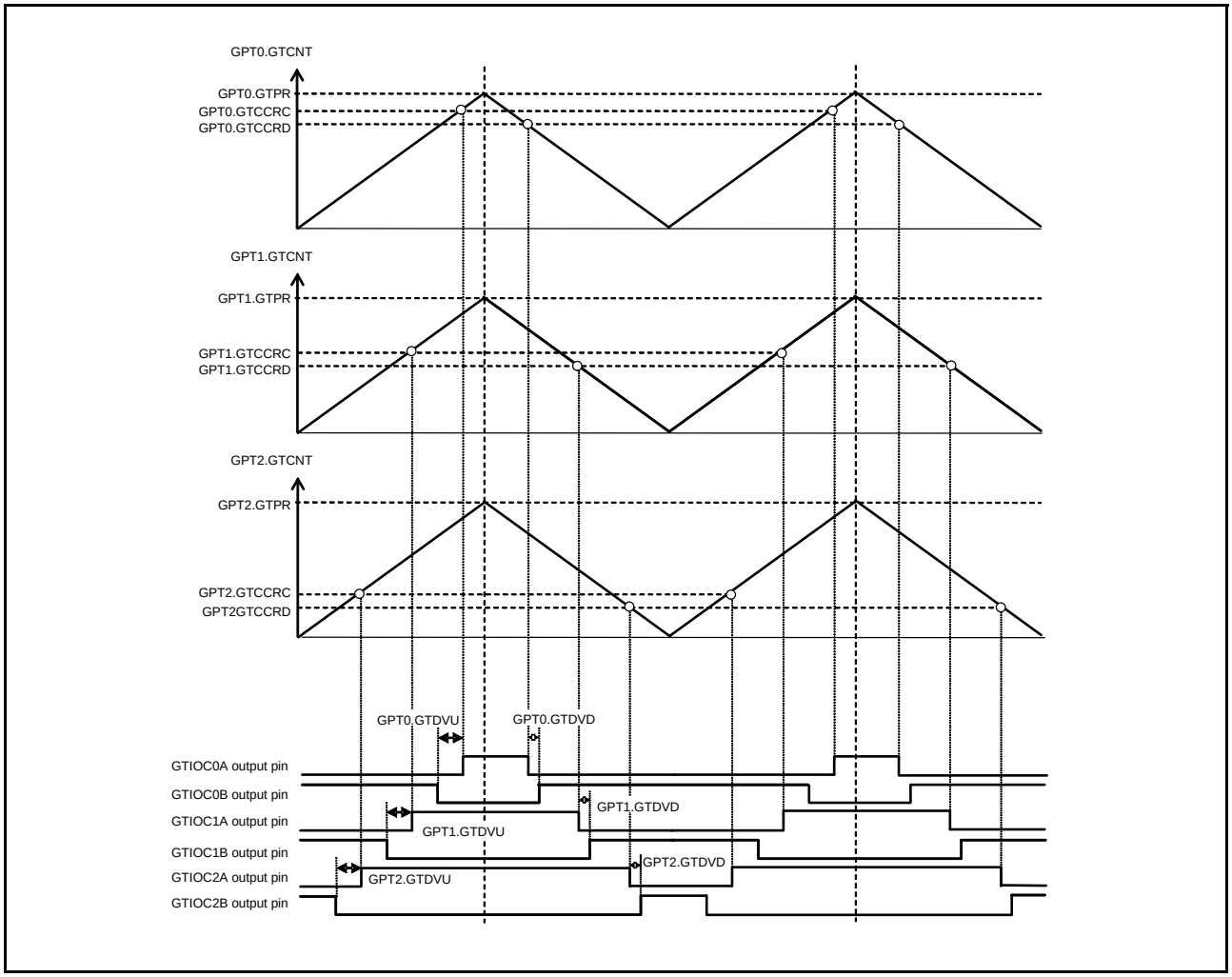


Figure 18.68 Example of Three-Phase Asymmetric Triangle-Wave Complementary PWM Output with Automatic Dead Time Setting

18.4 Interrupt Sources

18.4.1 Interrupt Sources and Priorities

There are four kinds of GPT interrupt sources; GTCCR input capture/compare match, GTCNT counter overflow (GTPR compare match)/underflow, dead time error, and LOCO count function interrupt. Each interrupt source has its own status flag and enable/disable bit, allowing the generation of interrupt request signals to be enabled or disabled individually When an interrupt source is generated, the corresponding status flag in GTST is set to 1. If the corresponding enable/disable bit in GTINTAD is set to 1 at this time, an interrupt is requested.
However, if a further interrupt is generated while the corresponding status flag is 1, the interrupt will be ignored. To enable the acceptance of an interrupt, the flag of the interrupt generation source should be 0.
Relative channel priorities can be changed by the interrupt controller; however the priority within a channel is fixed. For details, see section 11, Interrupt Controller (ICU). Table 18.6 lists the GPT interrupt sources.

Table 18.6 GPT Interrupt Sources (1 / 2)

Channel	Name	Interrupt Source		Interrupt Flag	DTC Activation	Priority
0	GTCIA0	GPT0.GTCCRA input capture/compare match		TCFA	Possible	High
	GTCIB0	GPT0.GTCCRB input capture/compare match		TCFB	Possible	
	GTCIC0	GPT0.GTCCRC compare match		TCFC	Possible	
		GPT0.GTCCRD compare match		TCFD		
		Dead time error		DTEF		
	GTCIE0	GPT0.GTCCRE compare match		TCFE	Possible	
		GPT0.GTCCRF compare match		TCFF		
	GTCIV0	GPT0.GTCNT overflow (GPT0.GTPR compare match)		TCFPO	Possible	
		GPT0.GTCNT underflow		TCFPU		
	LOCOI	LOCO count function interrupt	LCNT overflow	LISO	Possible	
			LOCO count value deviation exceedance	LISD		
			Frequency-divided LOCO clock rise	LISC		
		External trigger input	External trigger falling input	ETINF		
			External trigger rising input	ETIPF		
1	GTCIA1	GPT1.GTCCRA input capture/compare match		TCFA	Possible	
	GTCIB1	GPT1.GTCCRB input capture/compare match		TCFB	Possible	
	GTCIC1	GPT1.GTCCRC compare match		TCFC	Possible	
		GPT1.GTCCRD compare match		TCFD		
		Dead time error		DTEF		
	GTCIE1	GPT1.GTCCRE compare match		TCFE	Possible	
		GPT1.GTCCRF compare match		TCFF		
	GTCIV1	GPT1.GTCNT overflow (GPT1.GTPR compare match)		TCFPO	Possible	
		GPT1.GTCNT underflow		TCFPU		Low

Table 18.6 GPT Interrupt Sources (2 / 2)

Channel	Name	Interrupt Source	Interrupt Flag	DTC Activation	Priority
2	GTCIA2	GPT2.GTCCRA input capture/compare match	TCFA	Possible	High
	GTCIB2	GPT2.GTCCRB input capture/compare match	TCFB	Possible	
	GTCIC2	GPT2.GTCCRC compare match	TCFC	Possible	
		GPT2.GTCCRD compare match	TCFD		
		Dead time error	DTEF		
	GTCIE2	GPT2.GTCCRE compare match	TCFE	Possible	
		GPT2.GTCCRF compare match	TCFF		
	GTCIV2	GPT2.GTCNT overflow (GPT2.GTPR compare match)	TCFPO	Possible	
		GPT2.GTCNT underflow	TCFPU		
3	GTCIA3	GPT3.GTCCRA input capture/compare match	TCFA	Possible	
	GTCIB3	GPT3.GTCCRB input capture/compare match	TCFB	Possible	
	GTCIC3	GPT3.GTCCRC compare match	TCFC	Possible	
		GPT3.GTCCRD compare match	TCFD		
		Dead time error	DTEF		
	GTCIE3	GPT3.GTCCRE compare match	TCFE	Possible	
		GPT3.GTCCRF compare match	TCFF		
	GTCIV3	GPT3.GTCNT overflow (GPT3.GTPR compare match)	TCFPO	Possible	
		GPT3.GTCNT underflow	TCFPU		Low

Note: • This table shows the initial state immediately after a reset. The relative channel priorities can be changed by the interrupt controller.

(1) Input Capture/Compare Match Interrupt

If the corresponding interrupt enable bit in GTINTAD is 1 when a GTCCR input capture/compare match in each channel occurs, an interrupt is requested.

(2) Overflow/Underflow (Periodic) Interrupt

A periodic interrupt whose generation interval is determined by GTPR of each channel can be generated.
For saw-waves, the GTST.TCFPO flag is set to 1 when the GTCNT counter value matches GTPR (overflow) in up-count operation, the GTST.TCFPU flag is set to 1 when GTCNT reaches 0 (underflow) in down-count operation, and a GTCIV interrupt request is generated if the bits that correspond to GTINTPR.GTINTPR[1:0] are set to 01b, 10b, or 11b.
For triangle waves, GTST.TCFPO flag is set to 1 when the GTCNT counter value matches GTPR (crest) in up-count operation, the GTST.TCFPU flag is set to 1 when GTCNT reaches 0 (trough) in down-count operation, and a GTCIV interrupt request is generated if bits that correspond to GTINTPR.GTINTPR[1:0] are set to 01b, 10b, or 11b.

(3) LOCO Count Function Interrupt

When the frequency-divided LOCO clock rising is detected, LOCO count value exceeds the specified deviation, or an overflow occurs in the LCNT counter, the corresponding status flag in LCST is set to 1. If the corresponding interrupt enable bit in LCCR is 1 at this time, a LOCOI interrupt request is generated.
Similarly, when the GTETRG external trigger input rising or falling is detected, the corresponding status flag in GTETINT is set to 1. If the corresponding interrupt enable bit in GTETINT is 1 at this time, a LOCOI interrupt request is generated.

(4) Dead Time Error Interrupt

When automatic dead time setting has been made, the GTST.DTEF flag becomes 1 when the timer output toggle point with dead time added exceeds the timer cycle. If GTINTAD.EINT is 1 at this time, a LOCOI interrupt request is generated.

Table 18.7 Interrupt Signals, Interrupt Enable Bits, and Status Flags

Interrupt Signal	Interrupt Enable Bit	Status Flag
GTCIV	GTINTAD[7:6](GTINTPR[1:0])	GTST[7] (TCFPU)
		GTST[6] (TCFPO)
GTCIE	GTINTAD[5] (GTINTF)	GTST[5] (TCFF)
	GTINTAD[4] (GTINTE)	GTST[4] (TCFE)
GTCIC	GTINTAD[11](EINT)	GTST[11] (DTEF)
	GTINTAD[3] (GTINTD)	GTST[3] (TCFD)
	GTINTAD[2] (GTINTC)	GTST[2] (TCFC)
GTCIB	GTINTAD[1] (GTINTB)	GTST[1] (TCFB)
GTCIA	GTINTAD[0] (GTINTA)	GTST[0] (TCFA)
LOCOI	LCCR[6] (LCINTO)	LCST[2] (LISO)
	LCCR[5] (LCINTD)	LCST[1] (LISD)
	LCCR[4] (LCINTC)	LCST[0] (LISC)
	GTETINT[1] (ETINEN)	GTETINT[9] (ETINF)
	GTETINT[0] (ETIPEN)	GTETINT[8] (ETIPF)

(5) Points for Caution when Interrupt Sources Are in Use at the Same Time

For the GTCICn, GTCIEn, GTCIVn, LOCOI (n=0, 1, 2, 3) interrupts, which have multiple interrupt sources, if the value of the interrupt request (IR) flag in ICUA is becoming 1 due to a request from a given interrupt source (for example, the TCFC flag in GTCICn) when another interrupt source (for example, the TCFD flag in GTCICn) generates an interrupt, the request from the other interrupt source (in this case, the TCFD flag in GTCICn) is ignored.
Accordingly, if the multiple interrupt sources of such an interrupt are to be used at the same time, confirm the values of all flags corresponding to the interrupt sources that are in use from within the interrupt handling routine, and ensure appropriate processing for all source flags that are currently set.

18.4.2 DTC Activation

The DTC can be activated by the interrupt in each channel. For details, see section 11, Interrupt Controller (ICU), and section 14, Data Transfer Controller (DTC).
However, as similar to the interrupt handling, if a further DTC activation request is generated while the corresponding status flag is 1, the interrupt will be ignored. To enable the acceptance of an interrupt, the flag of the interrupt generation source should be 0.

18.4.3 Interrupt and A/D Conversion Request Skipping Function

By setting the GTITC register, the GTCNT counter overflows (GTPR compare matches)/underflow interrupts (GTCIV) can be skipped. Other interrupts and A/D converter start request signals can be skipped in coordination with the GTCIV skipping function. However, the dead time error interrupts cannot be linked with the GTCIV skipping function. If an interrupt is skipped, the change in the corresponding status flag is also skipped and the skipping function operates while the status flag is set.
When both troughs and crests are counted and skipped in triangle-wave mode, if the number of times of skipping is odd, GTCIV interrupt requests cannot be generated at troughs only or at crests only depending on the skipping counter start timing. Therefore, in order to count both troughs and crests and generate the GTCIV interrupts at troughs only or crests only in triangle-wave mode, the number of times of skipping should be even.
Similarly, in saw-wave mode, when both overflows and underflows are counted and skipped with the count direction changed, GTCIV interrupt requests cannot be generated at overflows only or at underflows only. Therefore, in order to count both overflows and underflows with the count direction changed and generate the GTCIV interrupts at overflows only or underflows only in saw wave mode, the skipping state should be carefully checked before using.
When changing the skipping count, be sure to release the skipping count setting (GTITC.IVTC[1:0] = 00b).
Figure 18.69 to Figure 18.74 show examples of skipping function operation.

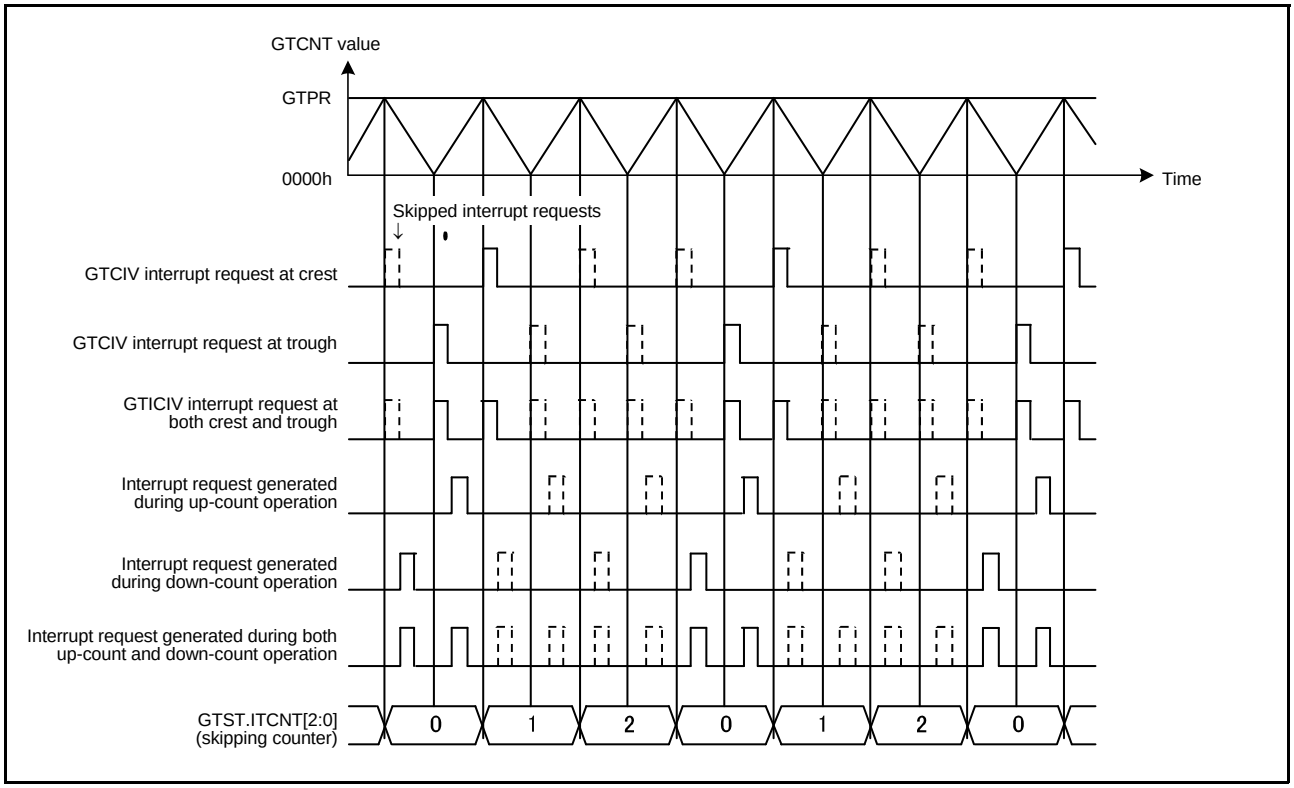


Figure 18.69 Example of Interrupt Skipping Function Operation (Triangle Waves, Counting and Skipping Crests, Skipping Count: 2)

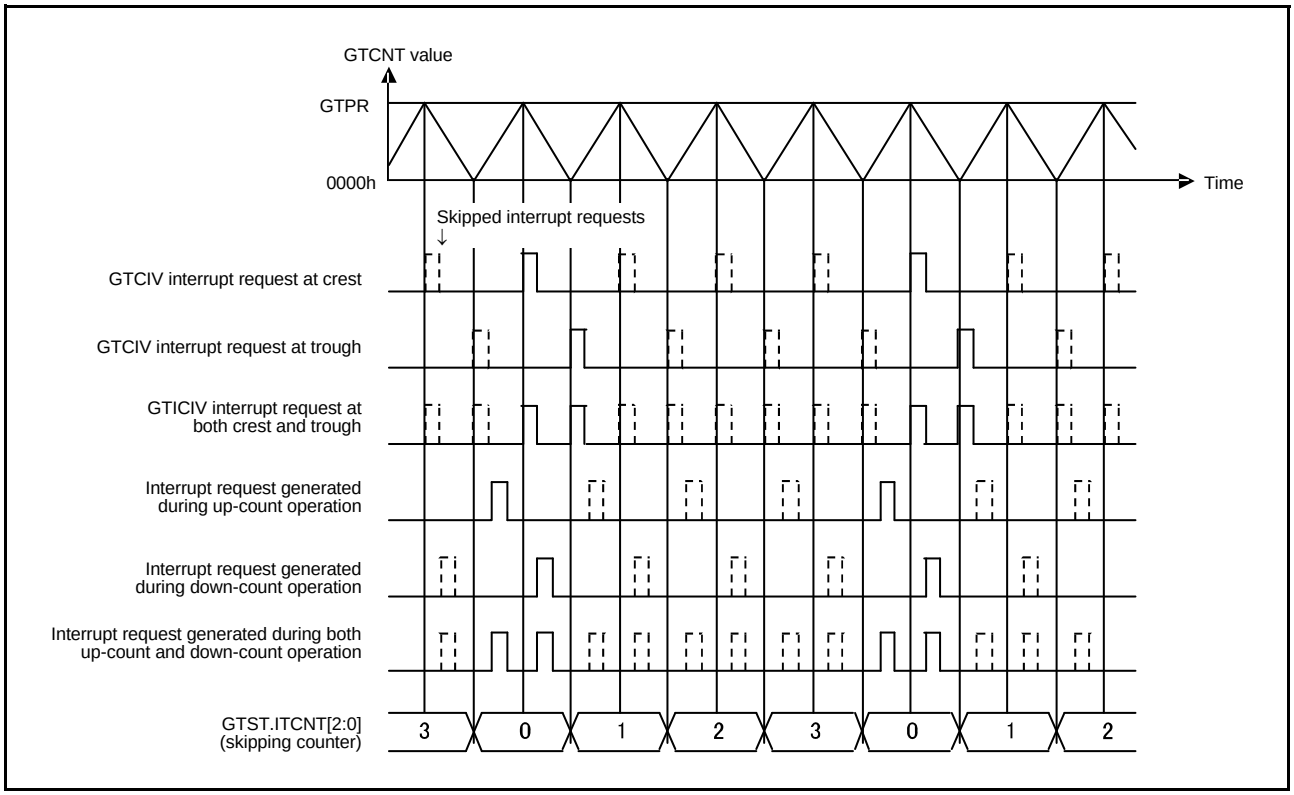


Figure 18.70 Example of Interrupt Skipping Function Operation (Triangle Waves, Counting and Skipping Troughs, Skipping Count: 3)

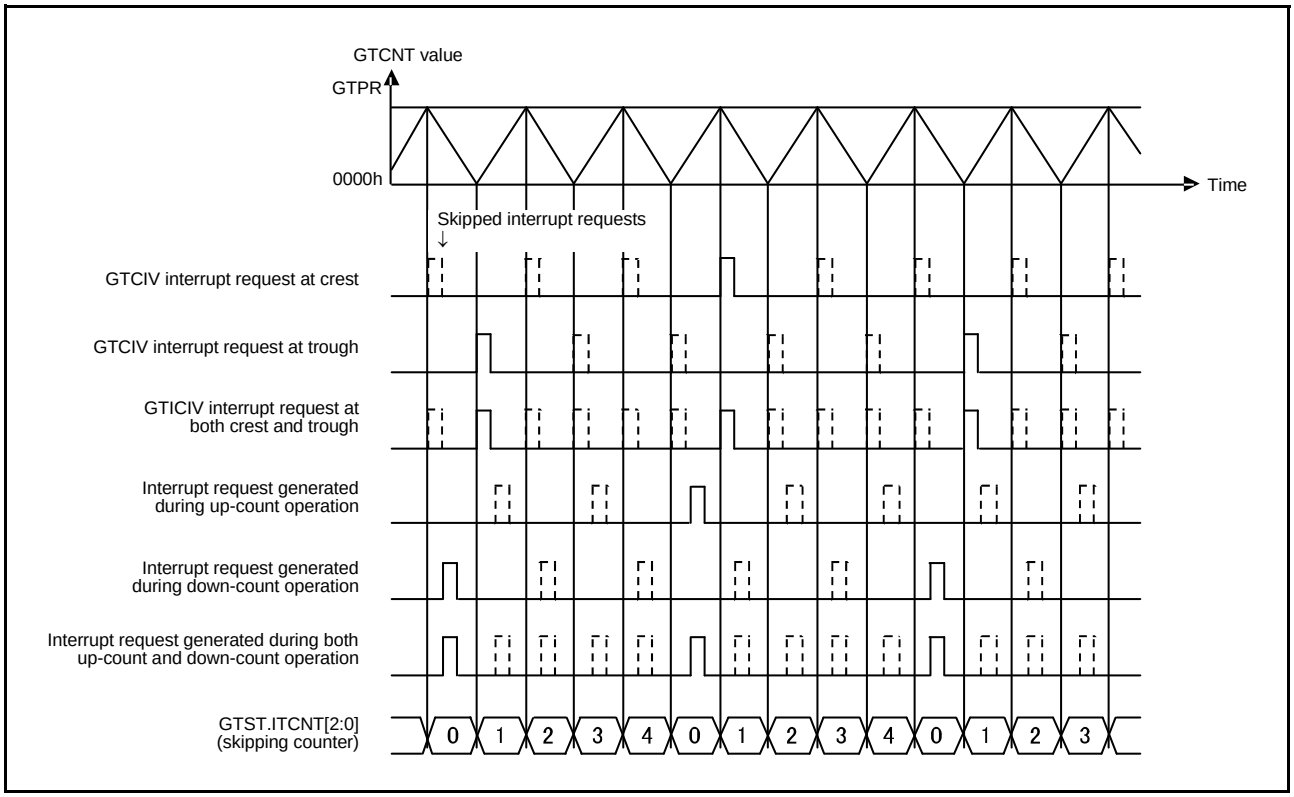


Figure 18.71 Example of Interrupt Skipping Function Operation (Triangle Waves, Counting and Skipping Both Troughs and Crests, Skipping Count: 4)

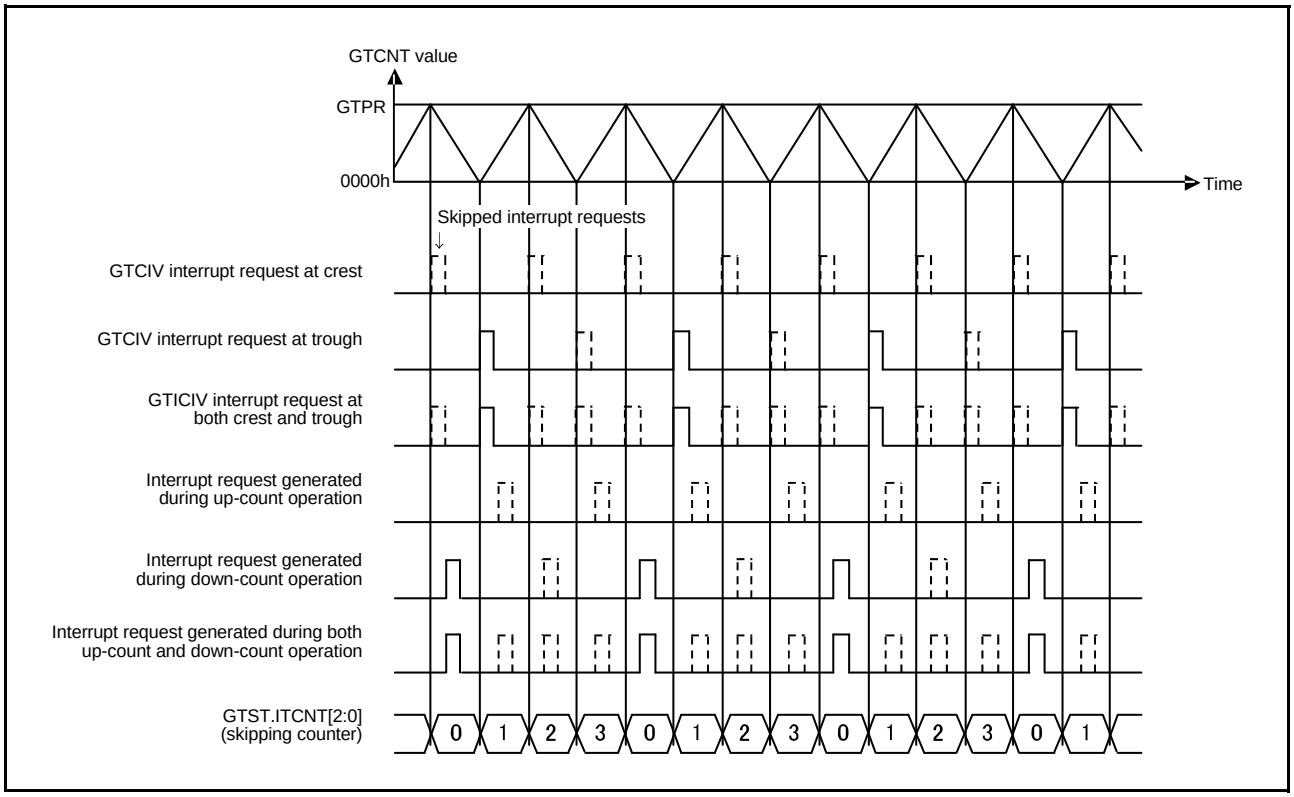


Figure 18.72 Example of Interrupt Skipping Function Operation (Triangle Waves, Counting and Skipping Both Troughs and Crests, Skipping Count: 3, Skipping Started at Up-Counting)

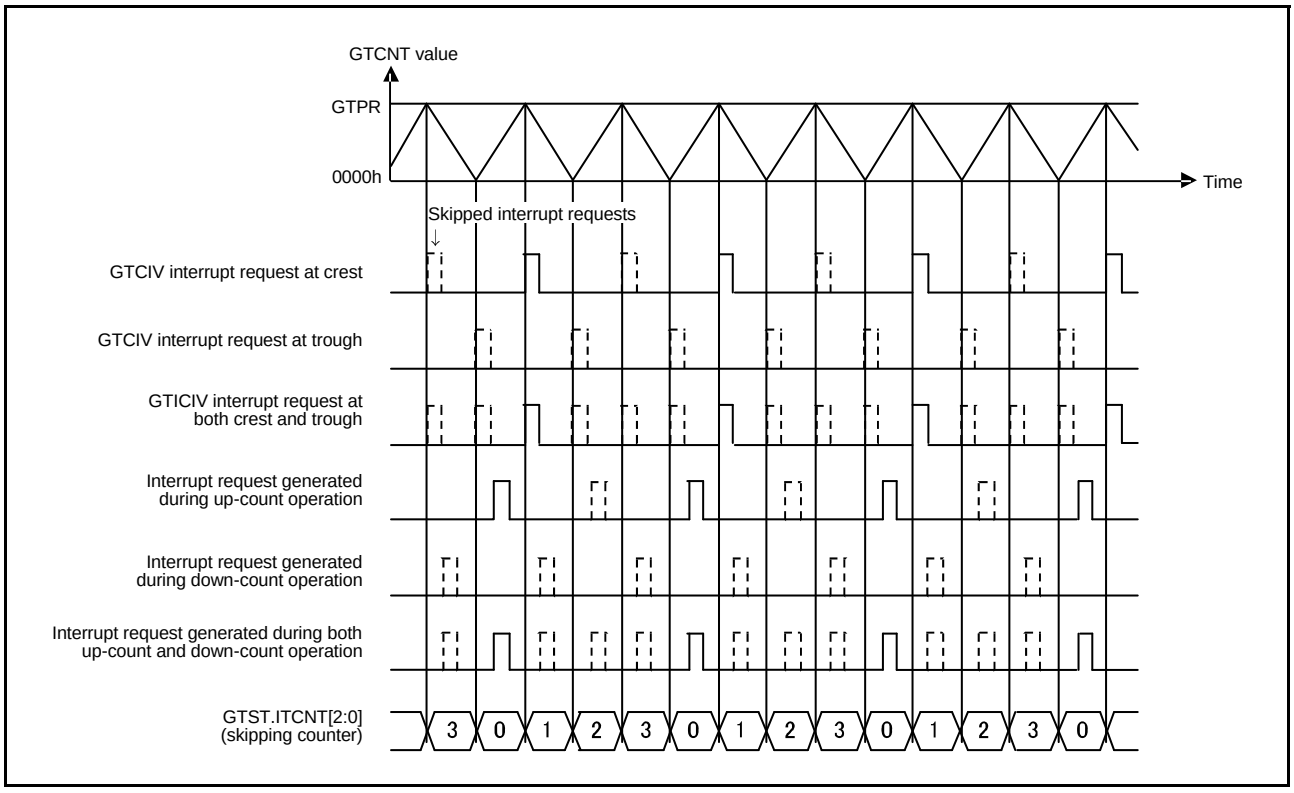


Figure 18.73 Example of Interrupt Skipping Function Operation (Triangle Waves, Counting and Skipping Both Troughs and Crests, Skipping Count: 3, Skipping Started at Down-Counting)

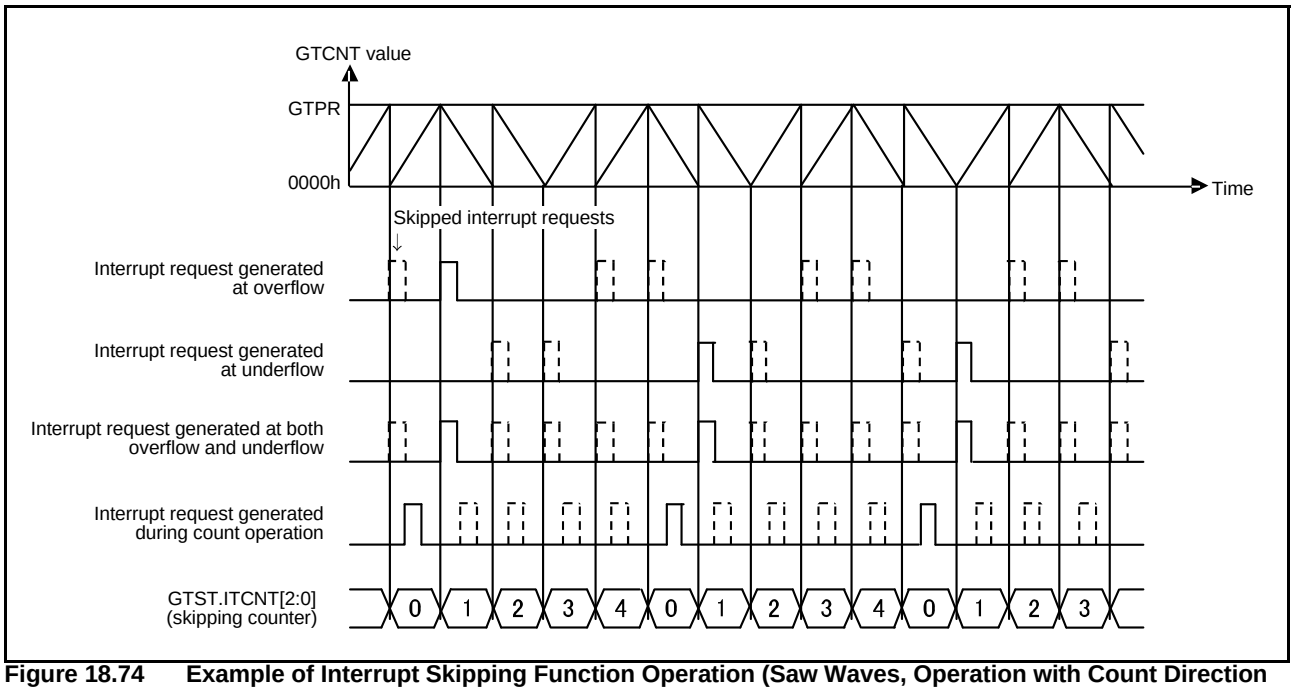


Figure 18.74 Example of Interrupt Skipping Function Operation (Saw Waves, Operation with Count Direction Changed, Counting and Skipping Both Overflows and Underflows, Skipping Count: 4)

18.5 A/D Converter Start Request

An A/D converter start request can be issued at a compare match between the GTCNT counter and GTADTRA or GTADTRB, and up-counting only, down-counting only, or both up-counting and down-counting can be specified. GTADTRA and GTADTRB each has two buffer registers. Buffer operation with GTADTRA used together with GTADTBRA and GTADTDBRA, and buffer operation with GTADTRB used together with GTADTBRB and GTADTDBRB can be performed.

Figure 18.75 shows an example of A/D converter start request operation, and Figure 18.76 shows an example for setting A/D converter start request operation.

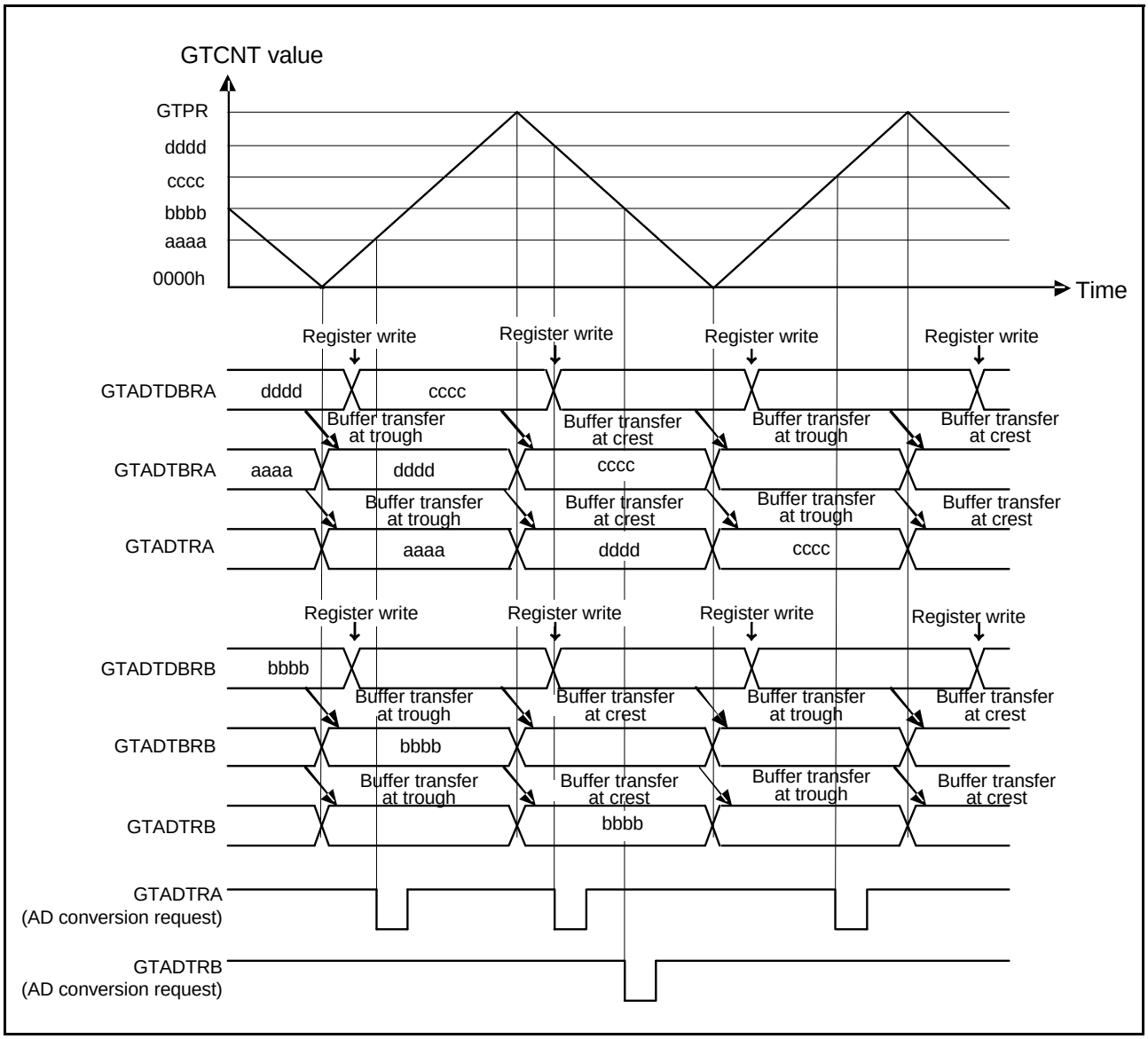


Figure 18.75 Example of A/D Converter Start Request Timing Operation (Triangle Waves, Double Buffer Operation, Buffer Transfer at Both Troughs and Crests, A/D Converter Start Requested by GTADTRA0 at Both Up-Counting and Down-Counting, A/D Converter Start Requested by GTADTRB0 at Down-Counting,)

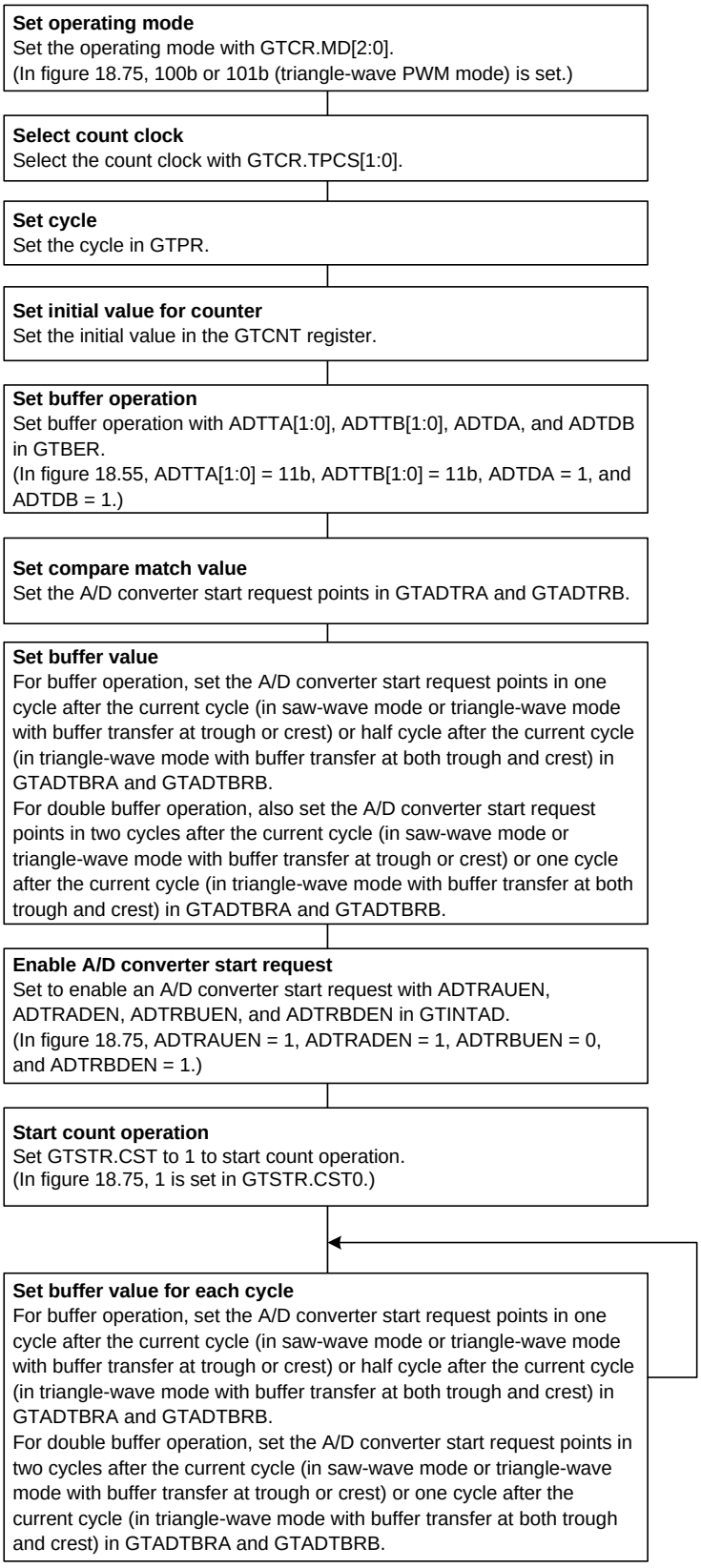


Figure 18.76 Example for Setting A/D Converter Start Request Timing Operation

18.6 LOCO Count Function

The GPT can measure the cycle of the frequency-divided LOCO clock used for the independent watchdog timer (IWDT) in the RX62T. By this function, the main clock oscillation frequency errors can be detected.
The target LOCO clock to be measured (frequency-divided LOCO clock) can be selected from the LOCO clock/1, LOCO clock/16, LOCO clock/128, and LOCO clock/256, and the count clock for measuring the frequency-divided LOCO clock can be selected from ICLK/1, ICLK/2, ICLK/4, and ICLK/8.
The LCNT counter counts the frequency-divided LOCO clock cycle with the count clock, and the recent 16 count results are stored in LCNT0 to LCNT15 (the latest count result in LCNT00). The average value of the recent 16 count results is automatically computed and stored in LCNTA.
The frequency-divided LOCO clock rise interrupt requests can be generated when the rising edge of the frequency-divided LOCO clock is detected. The frequency-divided LOCO clock rise interrupt requests can be skipped, and the count results can also be skipped. When the count result (LCNT00 value) exceeds the upper limit or lower limit value, the LOCO deviation exceedance interrupt request can be generated. The upper and lower limits can be set in LCNTDU and LCNTDL, respectively, and the upper limit value is obtained by (LCNTA value + LCNTDU value) and the lower limit value is obtained by (LCNTA value – LCNTDL value). When the frequency-divided LOCO clock frequency is too low and the LCNT counter overflows, the LCNT overflow interrupt request can be generated. Since all of these interrupts are output as LOCOI interrupts, the interrupt source should be determined by reading the status flags after the interrupt generation.
When using the LOCO count function, the independent watchdog timer (IWDT) should be activated.
Table 18.8 shows a frequency setting example for the LOCO count function.
Figure 18.77 shows an example of LOCO count function operation, and Figure 18.78 shows the setting flow example.

Table 18.8 Frequency Setting Example for LOCO Count Function

Frequency-Divided LOCO Clock		Count Clock		
LCCR.LPSC[1:0] Setting	**Frequency**	**LCCR.TPSC[1:0] Setting**	**Frequency (When ICLK = 100 MHz)**	**Desired Count Result Value**
00 (not divided)	125 KHz	00 (not divided)	100 MHz	320h
01 (divided by 16)	7.81 KHz	00 (not divided)	100 MHz	3200h
10 (divided by 128)	976 Hz	10 (divided by 4)	25 MHz	6400h
11 (divided by 256)	488 Hz	11 (divided by 8)	12.5 MHz	6400h

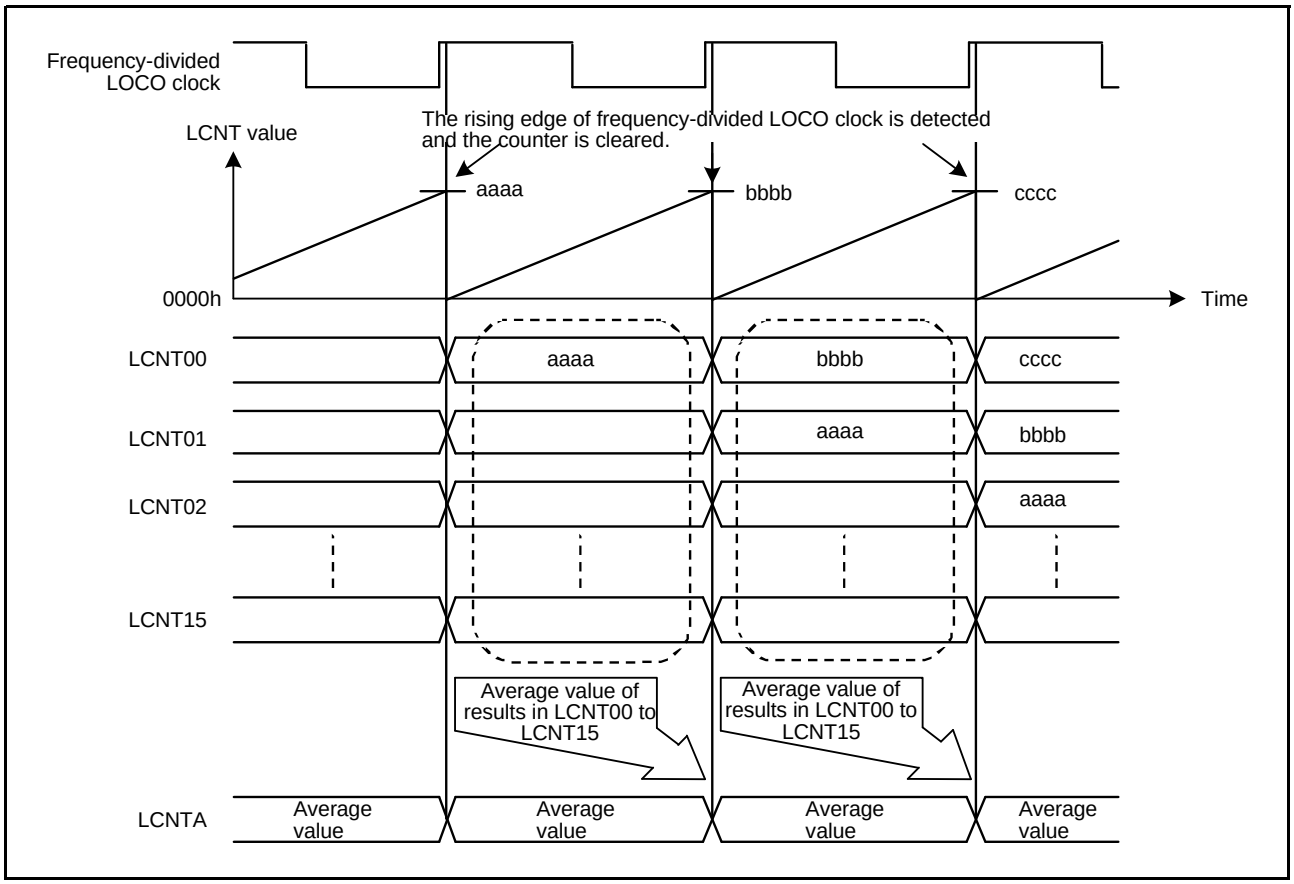


Figure 18.77 Example of LOCO Count Function Operation

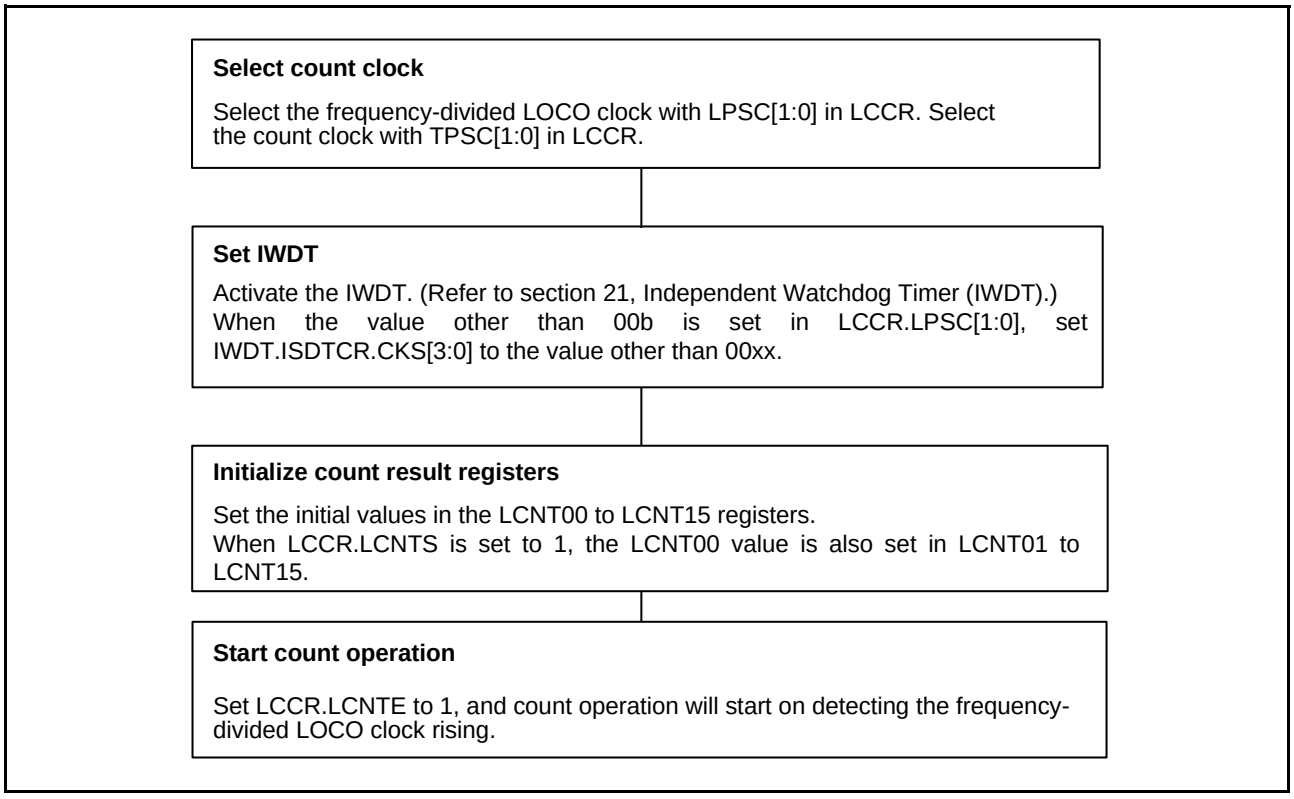


Figure 18.78 Example for Setting LOCO Count Function Operation

The frequency-divided LOCO clock rise interrupt requests can be skipped, and the count results can also be skipped. The skipping count can be selected from 7, 15, 127, and 255 times with LCCR.LCTO[2:0]. Whether to skip the count results is set with LCCR.LCNTAT.

Figure 18.79 shows an example in which the count result is not skipped, and Figure 18.80 shows an example in which the count result is also skipped.

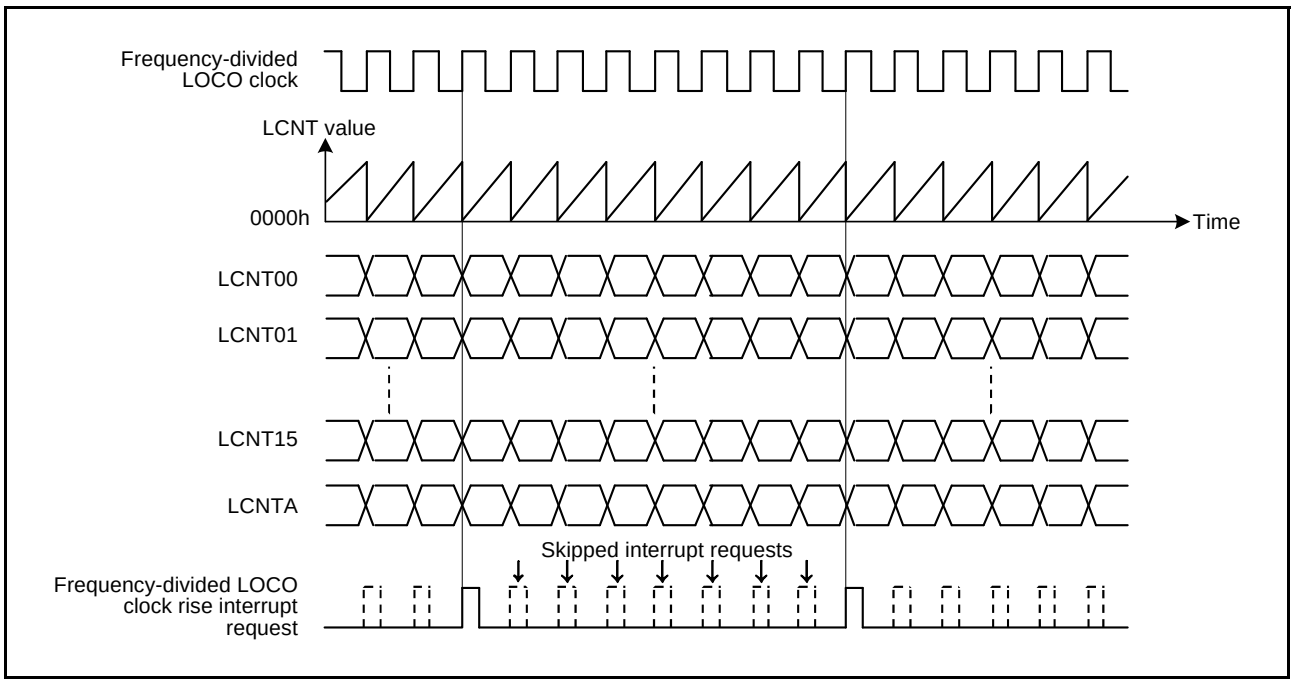


Figure 18.79 Example of LOCO Count Skipping Function Operation (Skipping Count: 7, Count Result not Skipped)

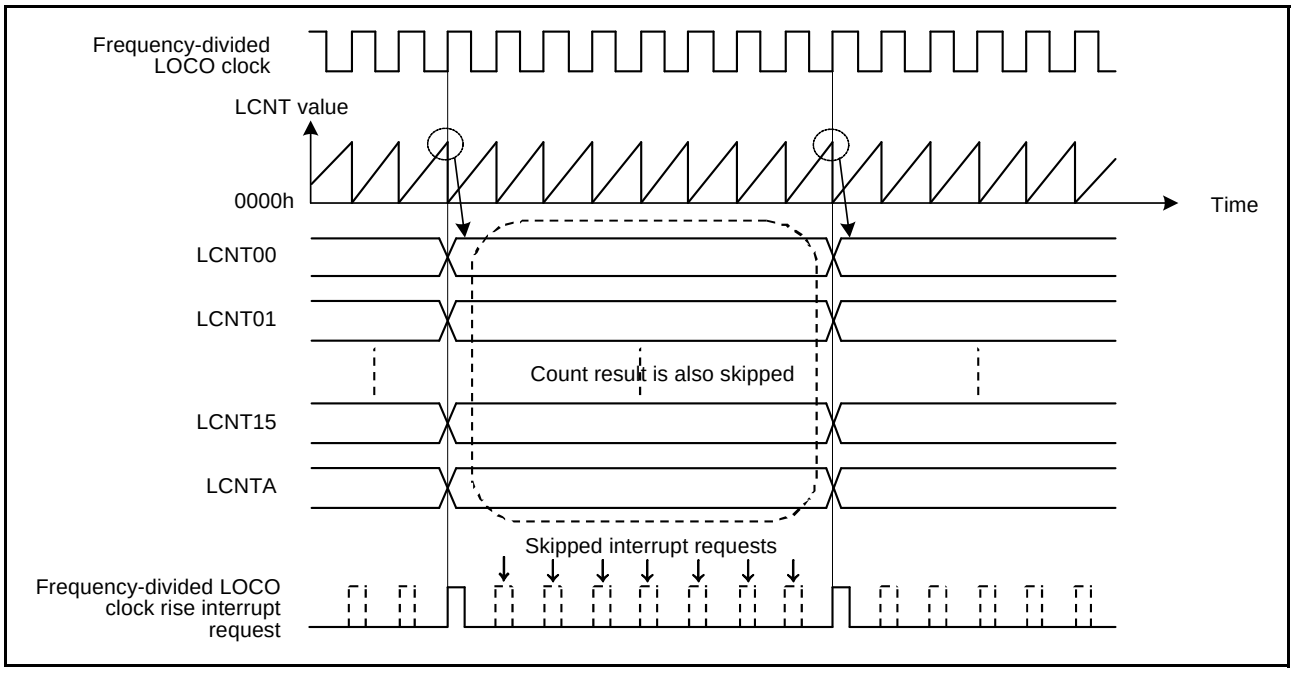


Figure 18.80 Example of LOCO Count Skipping Function Operation (Skipping Count: 7, Count Result Skipped)

18.7 Protection Function

18.7.1 Write-Protection for Registers

In order to prevent registers from being accidentally modified, registers can be write-protected in channel units by setting GTWP.WPn (n = 0 to 3).
The write-protection can be set for the following registers:

GPTn.GTIOR, GPTn.GTINTAD, GPTn.GTCR, GPTn.GTBER, GPTn.GTUDC, GPTn.GTITC, GPTn.GTST, GPTn.GTCNT, GPTn.GTCCRA, GPTn.GTCCRB, GPTn.GTCCRC, GPTn.GTCCRD, GPTn.GTCCRE, GPTn.GTCCRF, GPTn.GTPR, GPTn.GTPBR, GPTn.GTPDBR, GPTn.GTADTRA, GPTn.GTADTBRA, GPTn.GTADTDBRA, GPTn.GTADTRB, GPTn.GTADTBRB, GPTn.GTADTDBRB, GPTn.GTONCR, GPTn.GTDTCR, GPTn.GTDVU, GPTn.GTDVD, GPTn.GTDBU, GPTn.GTDBD, GPTn.GTSOS, GPTn.GTSOS, GPTn.GTSOTR

18.7.2 Disabling of Buffer Operation

If the timing of buffer register write is too late for the buffer transfer timing, buffer operation can be suspended with the GTBDR setting. Specifically, buffer transfer can be temporarily disabled, even though a buffer transfer condition is generated during buffer register write, by setting the corresponding GTBDR bit to 1 (buffer operation disabled) before buffer register write and clearing the bit to 0 (buffer operation enabled) after completion of writing to all the buffer registers.
Figure 18.81 shows an example of operation for disabling buffer operation

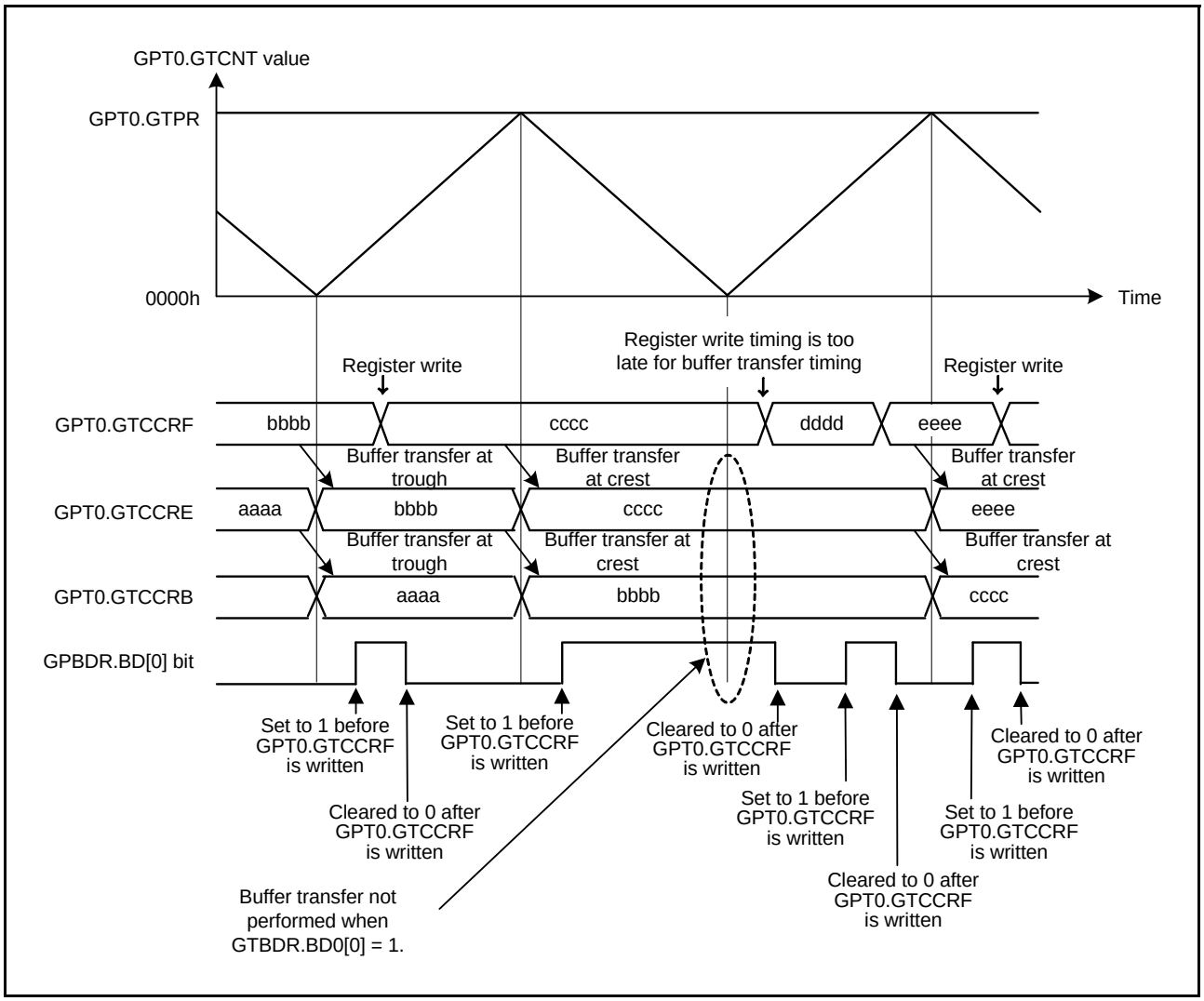


Figure 18.81 Example of Operation for Disabling Buffer Operation (Triangle Waves, Double Buffer Operation, Buffer Transfer at Both Troughs and Crests)

18.7.3 GTIOC Pin Output Negate Control

For protection from system failure, the negate control (deactivating the output level) is provided for GTIOC pin output with the GTONCR setting. There are three negate control sources: the comparator detection, GTETRG pin input, and writing to GTONCR.SWN.

Figure 18.82 shows an example of the GTIOC pin output negate control operation.

Note that once the negate control is performed, the negate control will not be released in the same cycle if the negate condition is no longer satisfied. The negate control is released in the next cycle.

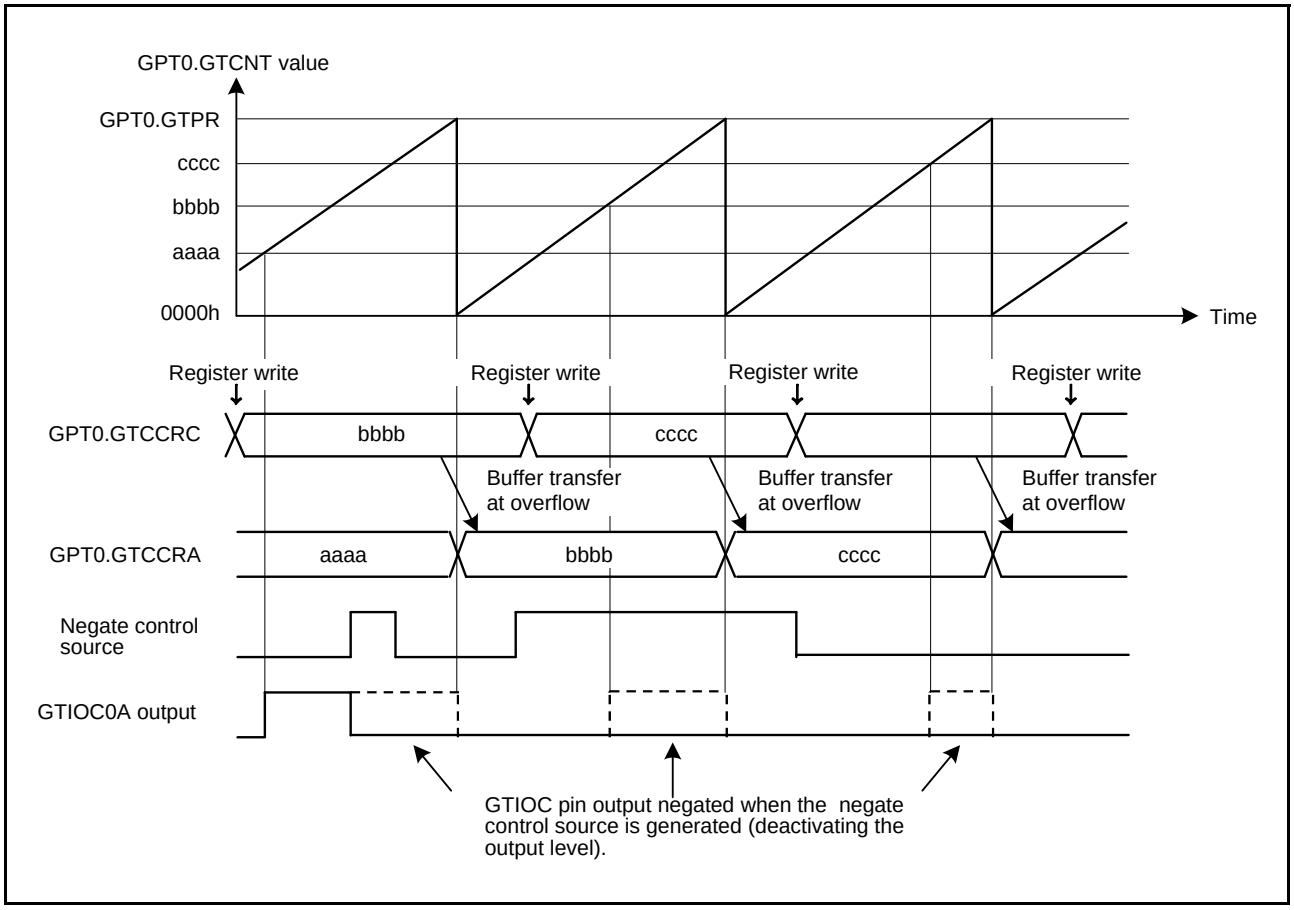


Figure 18.82 Example of GTIOC Pin Output Negate Control Operation (Saw-Wave Up-Counting, Buffer Operation, Active Level: 1, High Output at GTCCRA Compare Match, Low Output at Cycle End)

18.7.4 Output Protection Function for GTIOC Pin Output

In preparation for incorrect GTCCRA settings (settings outside the range of 0 < GTCCRA < GTPR), the output protection function for the GTIOC pin output (disabling function) is activated when the automatic dead time setting (GTDTCR.TDE = 1) is made in triangle-wave mode.
The status of the output protection function can be read from GTSOS.SOS[1:0].
Figure 18.83 shows the output protection function state transition.

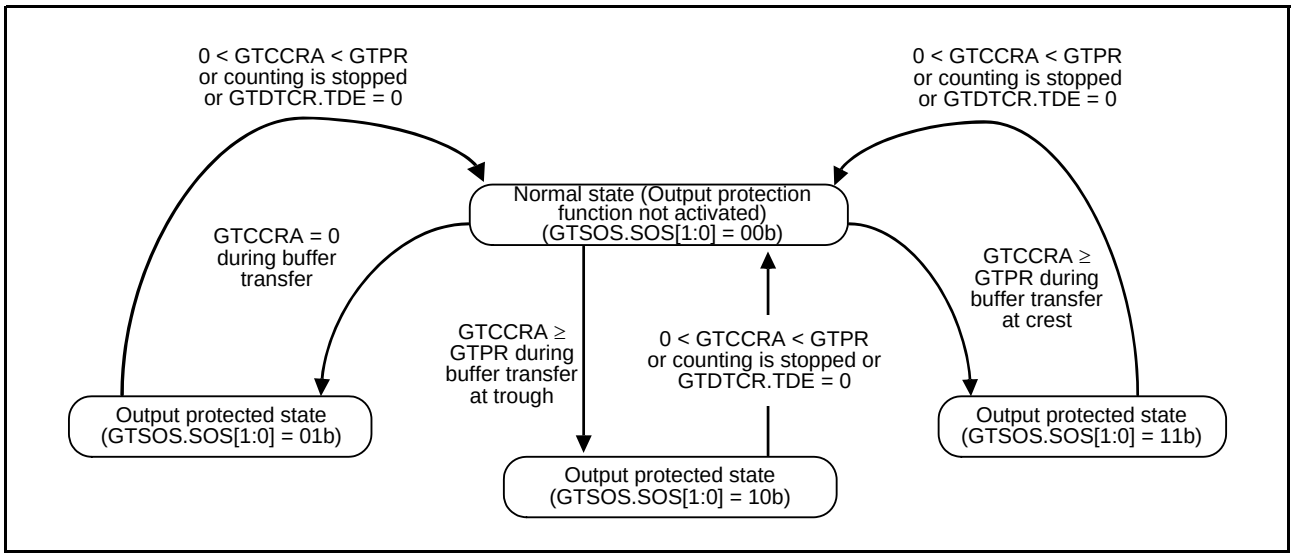
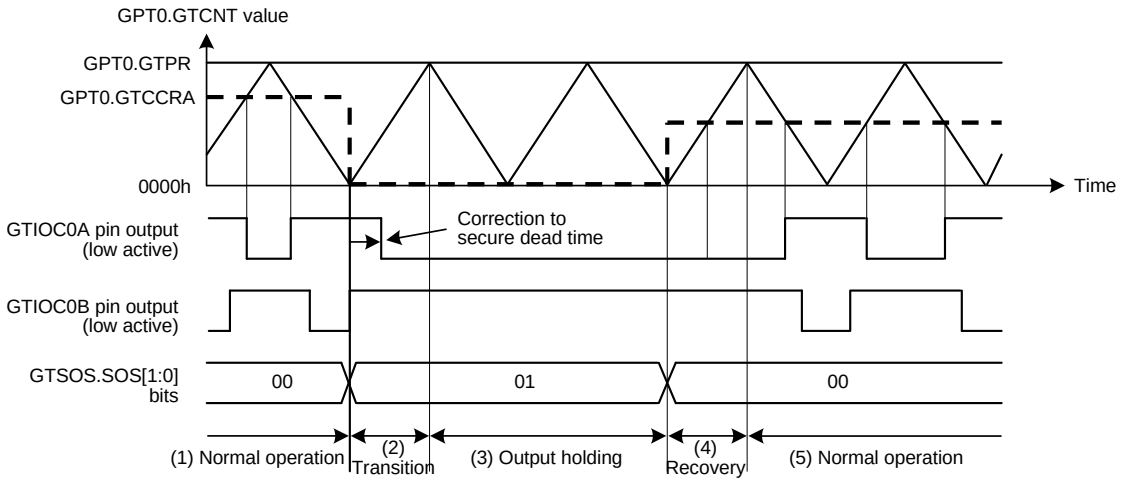


Figure 18.83 Output Protection Function

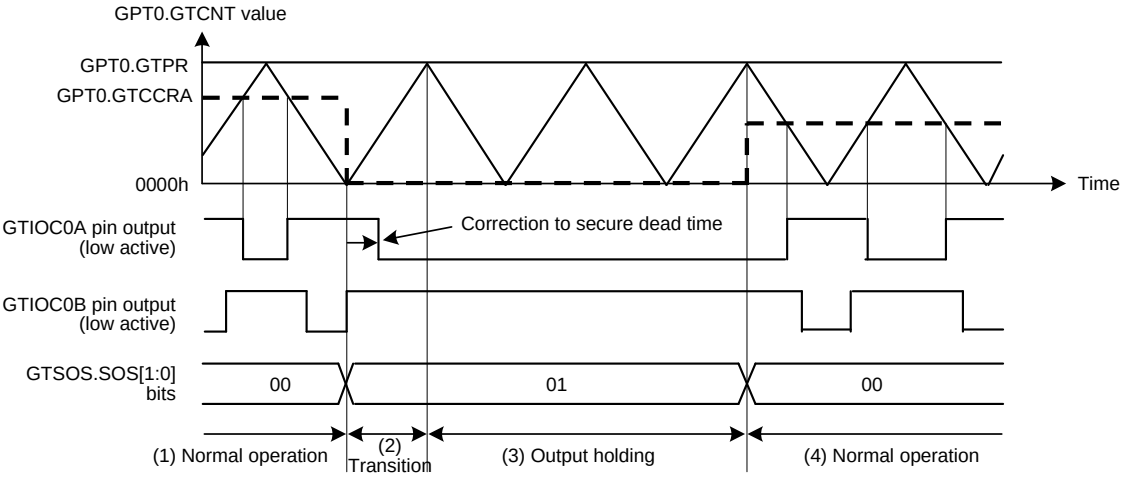
(1) Output Protection Function When GTCCRA is Set to 0 during Buffer Transfer

Figure 18.84 and Figure 18.85 show examples of output protection function operation when GTCCRA is set to 0 during buffer transfer at troughs, and Figure 18.86 and Figure 18.87 show examples when GTCCRA is set to 0 during buffer transfer at crests.



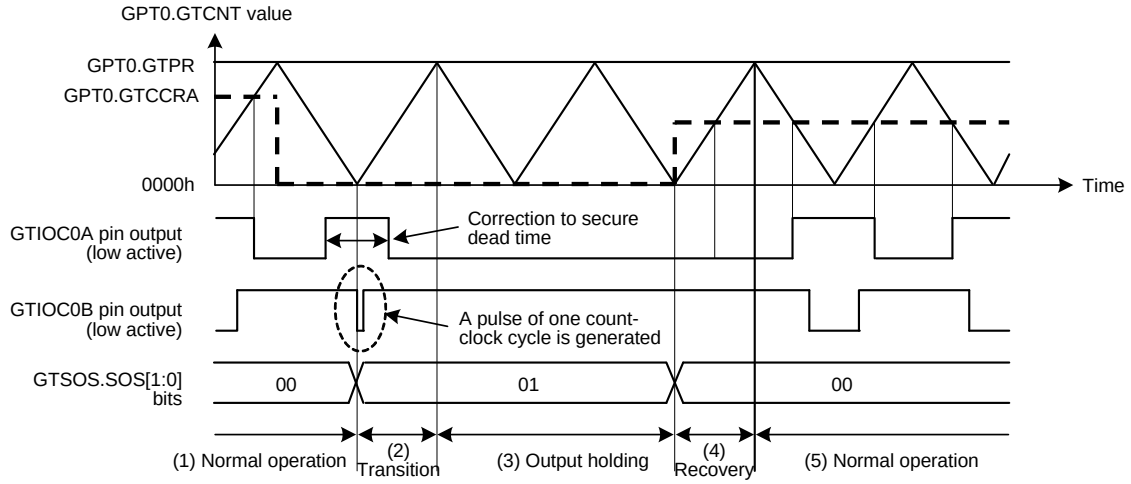
(1) Normal operation period: Toggle output due to a compare match is performed normally.
(2) Transition period: When GTCCRA = 0 is detected at the trough, the output protection status changes to GTSOS.SOS[1:0] = 01b, and toggle output is continued up to the next crest.
(3) Output holding period: The output is held while GTCCRA = 0.
(4) Recovery period: When 0 < GTCCRA < GTPR is detected at the trough, the output protection status changes to GTSOS.SOS[1:0] = 00b, and holding output is maintained up to the next crest.
(5) Normal operation period: Toggle output due to a compare match is performed normally.

Figure 18.84 Example of Output Protection Function Operation When GTCCRA is Set to 0 during Buffer Transfer at Troughs (Restored to 0<GTCCRA<GTPR during Buffer Transfer at Troughs, Active Level: Low)



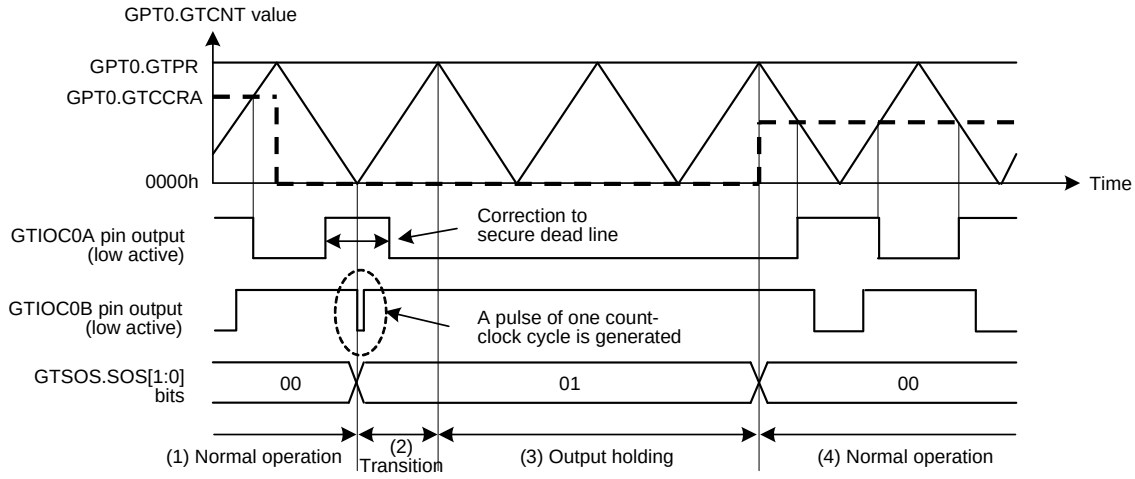
(1) Normal operation period: Toggle output due to a compare match is performed normally.
(2) Transition period: When GTCCRA = 0 is detected at the trough, the output protection status changes to GTSOS.SOS[1:0] = 01b, and toggle output is continued up to the next crest.
(3) Output holding period: The output is held while GTCCRA = 0.
(4) Normal operation period: When 0 < GTCCRA < GTPR is detected at the crest, the output protection status changes to GTSOS.SOS[1:0] = 00b, and toggle output due to a compare match is performed normally.

Figure 18.85 Example of Output Protection Function Operation When GTCCRA is Set to 0 during Buffer Transfer at Troughs (Restored to 0<GTCCRA<GTPR during Buffer Transfer at Crests, Active Level: Low)



(1) Normal operation period: Toggle output due to a compare match is performed normally.
(2) Transition period: When GTCCRA = 0 is detected at the trough, the output protection status changes to GTSOS.SOS[1:0] = 01b, and toggle output is continued up to the next crest.
(3) Output holding period: The output is held while GTCCRA = 0.
(4) Recovery period: When 0 < GTCCRA < GTPR is detected at the trough, the output protection status changes to GTSOS.SOS[1:0] = 00b, and holding output is maintained up to the next crest.
(5) Normal operation period: Toggle output due to a compare match is performed normally.

Figure 18.86 Example of Output Protection Function Operation When GTCCRA is Set to 0 during Buffer Transfer at Crests (Restored to 0<GTCCRA<GTPR during Buffer Transfer at Troughs, Active Level: Low)

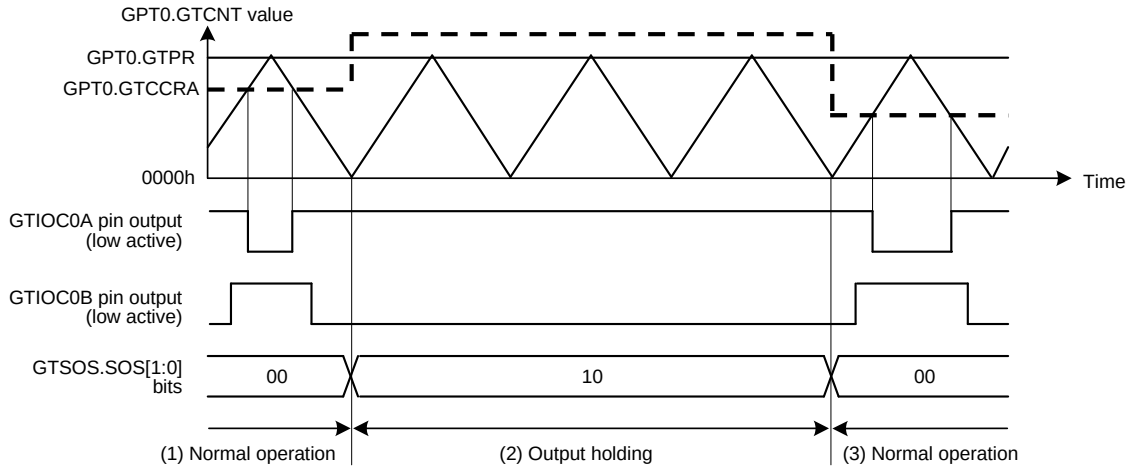


(1) Normal operation period: Toggle output due to a compare match is performed normally.
(2) Transition period: When GTCCRA = 0 is detected at the trough, the output protection status changes to GTSOS.SOS[1:0] = 01b, and toggle output is continued up to the next crest.
(3) Output holding period: The output is held while GTCCRA = 0.
(4) Recovery period: When 0 < GTCCRA < GTPR is detected at the crest, the output protection status changes to GTSOS.SOS[1:0] = 00b, and toggle output due to a compare match is performed normally.

Figure 18.87 Example of Output Protection Function Operation When GTCCRA is Set to 0 during Buffer Transfer at Crests (Restored to 0<GTCCRA<GTPR during Buffer Transfer at Crests, Active Level: Low)

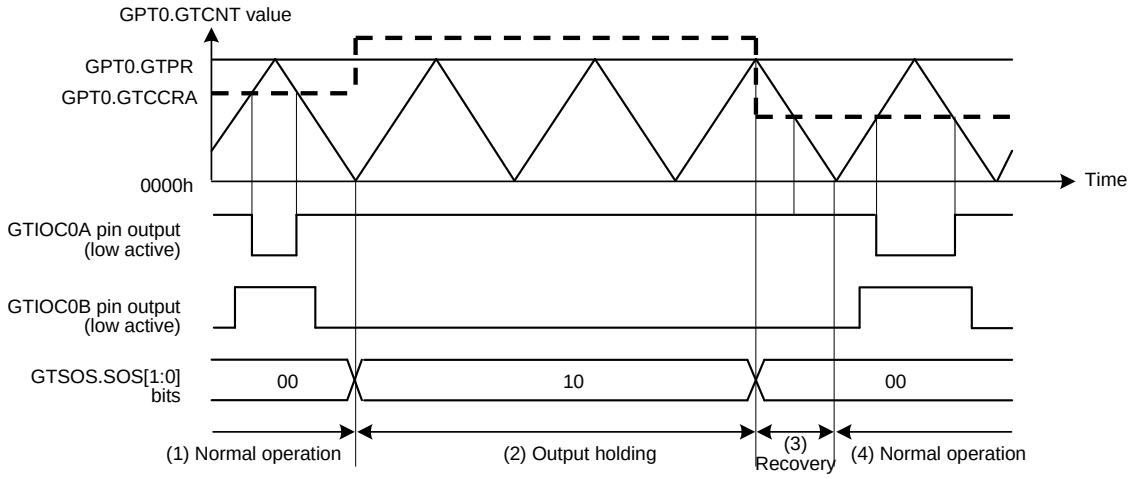
(2) Output Protection Function When GTCCRA ≥ GTPR is Set during Buffer Transfer at Troughs

Figure 18.88 and Figure 18.89 show examples of output protection function operation when GTCCRA ≥ GTPR is set during buffer transfer at troughs.



(1) Normal operation period: Toggle output due to a compare match is performed normally.
(2) Output holding period: When GTCCRA ≥ GTPR is detected at the trough, the output protection status changes to GTSOS[1:0] = 10b, and the output is held while GTCCRA ≥ GTPR.
(3) Normal operation period: When 0 < GTCCRA < GTPR is detected at the trough, the output protection status changes to GTSOS[1:0] = 00b, ant toggle output due to a compare match is performed normally.

Figure 18.88 Example of Output Protection Function Operation When GTCCRA ≥ GTPR is set during Buffer Transfer at Troughs (Restored to 0<GTCCRA<GTPR during Buffer Transfer at Troughs, Active Level: Low)

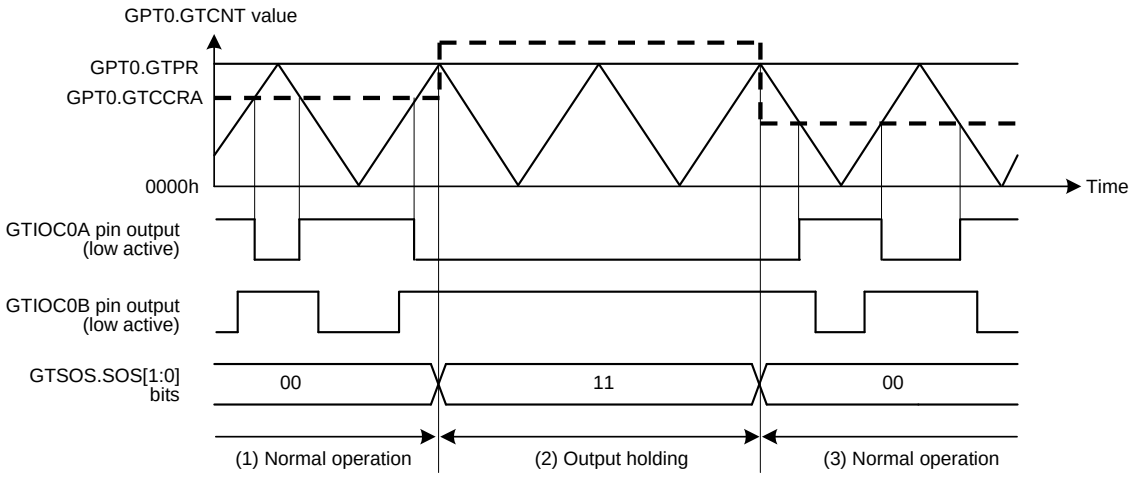


(1) Normal operation period: Toggle output due to a compare match is performed normally.
(2) Output holding period: When GTCCRA ≥ GTPR is detected at the trough, the output protection status changes to GTSOS[1:0] = 10b, and the output is held while GTCCRA ≥ GTPR.
(3) Recovery period: When 0 < GTCCRA < GTPR is detected at the crest, the output protection status changes to GTSOS.SOS[1:0] = 00b, and holding output is maintained up to the next trough.
(4) Normal operation period: Toggle output due to a compare match is performed normally.

Figure 18.89 Example of Output Protection Function Operation When GTCCRA ≥ GTPR is Set during Buffer Transfer at Troughs (Restored to 0<GTCCRA<GTPR during Buffer Transfer at Crests, Active Level: Low)

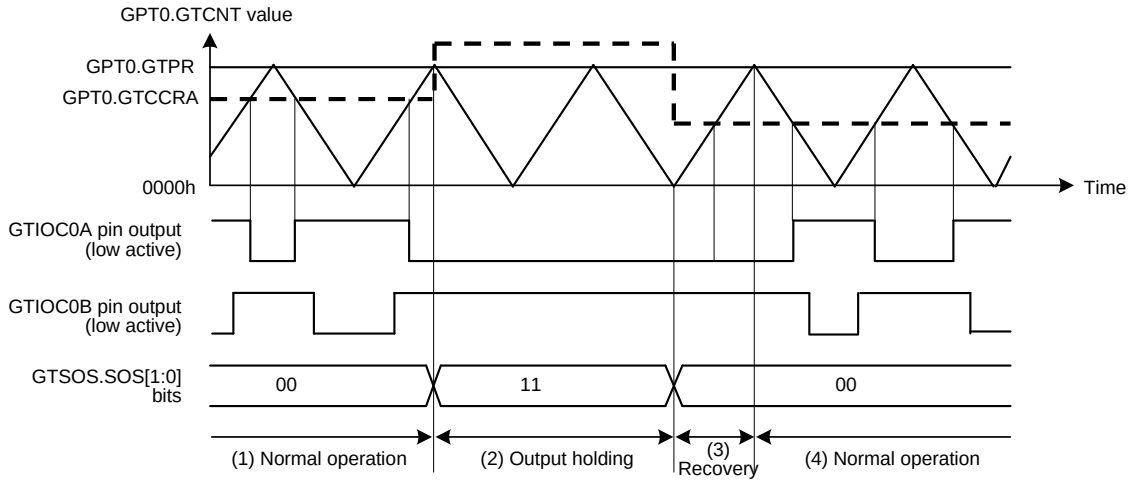
(3) Output Protection Function When GTCCRA ≥ GTPR is Set during Buffer Transfer at Crests

Figure 18.90 and Figure 18.91 show examples of output protection function operation when GTCCRA ≥ GTPR is set during buffer transfer at crests.



(1) Normal operation period: Toggle output due to a compare match is performed normally.
(2) Output holding period: When GTCCRA ≥ GTPR is detected at the crest, the output protection status changes to GTSOS[1:0] = 11b, and the output is held while GTCCRA ≥ GTPR.
(3) Recovery period: When 0 < GTCCRA < GTPR is detected at the crest, the output protection status changes to GTSOS.SOS[1:0] = 00b, and holding output is maintained up to the next trough.
(4) Normal operation period: Toggle output due to a compare match is performed normally.

Figure 18.90 Example of Output Protection Function Operation When GTCCRA ≥ GTPR is Set during Buffer Transfer at Crests (Restored to 0<GTCCRA<GTPR during Buffer Transfer at Crests, Active Level: Low)



(1) Normal operation period: Toggle output due to a compare match is performed normally.
(2) Output holding period: When GTCCRA ≥ GTPR Is detected at the crest, the output protection status changes to GTSOS[1:0] = 11b, and the output is held while GTCCRA ≥ GTPR.
(3) Recovery period: When 0 < GTCCRA < GTPR is detected at the trough, the output protection status changes to GTSOS.SOS[1:0] = 00b, and holding output is maintained up to the next crest.
(4) Normal operation period: Toggle output due to a compare match is performed normally.

Figure 18.91 Example of Output Protection Function Operation When GTCCRA ≥ GTPR is Set during Buffer Transfer at Crests (Restored to 0<GTCCRA<GTPR during Buffer Transfer at Troughs, Active Level: Low)

(4) Restricted Specification of Output Protection Function

The GTCCRA value must be set within the range of (0 < GTCCRA < GTPR) at count start.
If an incorrect value is set in GTCCRA during count operation, (a setting outside the range of 0 < GTCCRA < GTPR), the output protection function deactivates the level of one of the positive and negative outputs. However, the function does not operate correctly if counting starts with an incorrect value set in GTCCRA.

18.7.5 High-Impedance Control of GTIOC Pin Output by POE Function

For protection from system failure, the high-impedance state of the GTIOC pin output can be controlled by the port output enable (POE) function.
For details, see section 17, Port Output Enable 3 (POE3).

18.8 Initialization Method of Output Pins

18.8.1 Pin Settings after Reset

The GPT registers are initialized at a reset. Start counting after setting GTIOR and the OAE and OBE bits in GTONCR and outputting the GPT function to external pins.

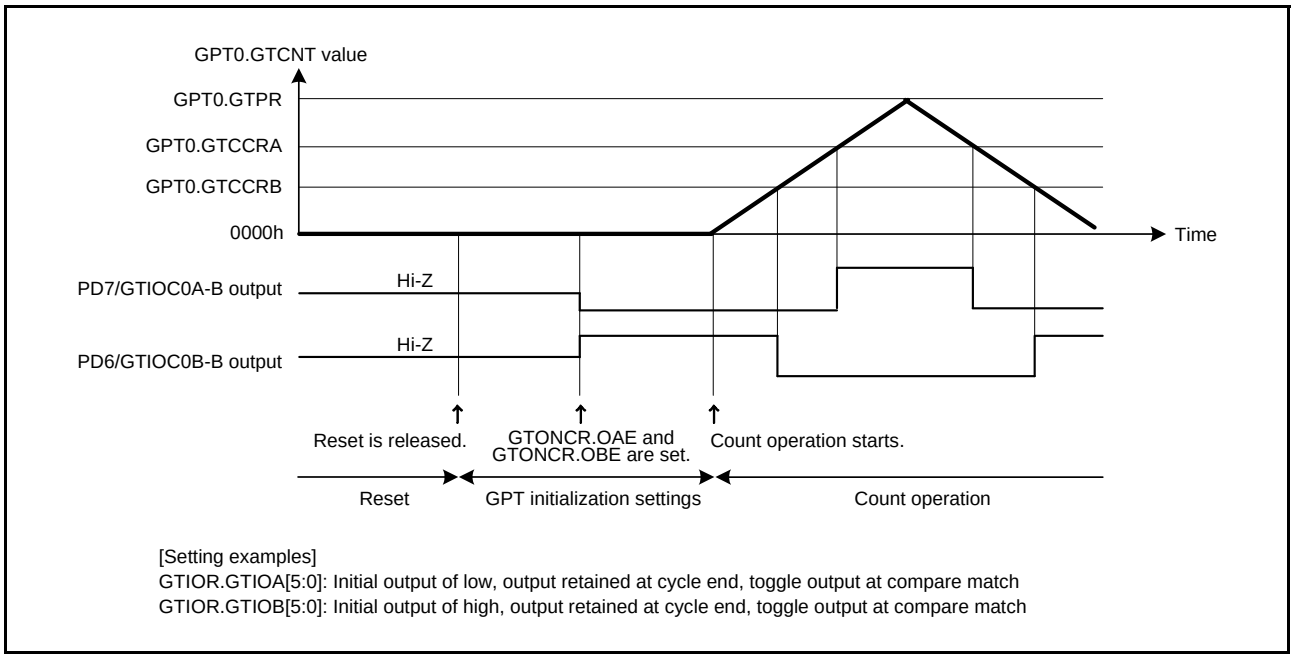


Figure 18.92 Example of Pin Settings after Reset

18.8.2 Pin Initialization Due to Error during Operation

If an error occurs during GPT operation, the following four types of pin processing can be performed before pin initialization.

(1) Set OAHLD and OBHLD bits in GTIOR to 1 and retain the outputs at count stop.
(2) Set OAHLD and OBHLD bits in GTIOR to 0, specify arbitrary output values at OADFLT and OBDFLT in GTIOR, and output the arbitrary values at count stop.
(3) Similar to the MTU3, previously set the pin to output an arbitrary value as a general output port by setting the DDR and DR registers of the I/O port. Set the OAE and OBE bits in GTONCR to 0 when an error occurs to allow the arbitrary values to be output from the pin set as a general output port.
(4) Drive the output to a high impedance state using the POE function of the port output enable 3 (POE3).

When automatic dead time setting has been made, clear the GTDTCR.TDE bit to 0 once after counting is stopped.

When counting is stopped, only the values of registers that are changed by a GPT external source will change. If counting is resumed, operation will carry on from where it was stopped.
If counting was stopped, registers should be initialized before counting is started.

18.9 Usage Notes

18.9.1 Module Stop Function Setting

Operation of the GPT can be disabled or enabled by the module stop control register. The initial setting is for operation of the GPT to be halted. Register access is enabled by clearing module stop state. For details, see section 9, Low Power Consumption.

18.9.2 Settings of GTCCRn during Compare Match Operation (n = A, B, C, D, E, F)

(1) When automatic dead time setting has been made in triangle-wave PWM mode

GTCCRA should be set within the range of GTDVU < GTCCRA, GTDVD < GTCCRA, and GTCCRA < GTPR. When the setting of GTCCRA = 0 or GTCCRA ≥ GTPR is made during count operation, the output protection function is activated.
Be sure to set 0 < GTCCRA < GTPR at count start. Otherwise, the output protection function is not be activated correctly. For details, refer to section 18.7.4, Output Protection Function for GTIOC Pin Output.

(2) When automatic dead time setting has not been made in triangle-wave PWM mode

GTCCRA should be set within the range of 0 < GTCCRA < GTPR. If GTCCRA = 0 or GTCCRA ≥ GTPR is set, a compare match occurs within the cycle only when GTCCRA = 0 or GTCCRA = GTPR is satisfied. In the case of GTCCRA > GTPR, no compare match occurs.
Similarly, GTCCRB should be set within the range of 0 < GTCCRB < GTPR. If GTCCRB = 0 or GTCCRA ≥ GTPR is set, a compare match occurs within the cycle only when GTCCRB = 0 or GTCCRB = GTPR is satisfied. In the case of GTCCRB > GTPR, no compare match occurs.

(3) When automatic dead time setting has been made in saw-wave one-shot pulse mode

GTCCRC and GTCCRD should be set to satisfy the following restrictions. If the restrictions are not satisfied, correct output waveforms with secured dead time may not be obtained.

- In up-count operation: GTCCRC < GTCCRD, GTCCRC > GTDVU, GTCCRD < GTPR - GTDVD
- In down-count operation: GTCCRC > GTCCRD, GTCCRC < GTPR – GTDVU, GTCCRD > GTDVD

Similarly, GTCCRE and GTCCRF should be set to satisfy the following restrictions. If the restrictions are not satisfied, correct output waveforms with secured dead time may not be obtained.

- In up-count operation: GTCCRE < GTCCRF, GTCCRE > GTDVU, GTCCRF < GTPR - GTDVD
- In down-count operation: GTCCRE > GTCCRF, GTCCRE < GTPR – GTDVU, GTCCRF > GTDVD

(4) When automatic dead time setting has not been made in saw-wave one-shot pulse mode

GTCCRC and GTCCRD should be set to satisfy the following restrictions. If the restrictions are not satisfied, two compare matches do not occur and pulse output cannot be performed.

- In up-count operation: 0 < GTCCRC < GTCCRD < GTPR
- In down-count operation: GTPR > GTCCRC > GTCCRD > 0

Similarly, GTCCRE and GTCCRF should be set to satisfy the following restrictions. If the restrictions are not satisfied, two compare matches do not occur and pulse output cannot be performed.

- In up-count operation: 0 < GTCCRE < GTCCRF < GTPR
- In down-count operation: GTPR > GTCCRE > GTCCRF > 0

(5) In saw-wave PWM mode

GTCCRA should be set with the range of 0 < GTCCRA < GTPR. If GTCCRA = 0 or GTCCRA = GTPR is set, a compare match occurs within the cycle only when GTCCRA = 0 or GTCCRA = GTPR is satisfied. If GTCCRA > GTPR is set, no compare match occurs.
Similarly, GTCCRB should be set with the range of 0 < GTCCRB < GTPR. If GTCCRB = 0 or GTCCRB = GTPR is set, a compare match occurs within the cycle only when GTCCRB = 0 or GTCCRB = GTPR is satisfied. If GTCCRB > GTPR is set, no compare match occurs.

18.9.3 Stopping the Timer in the Safe Way

When the timer stopping by the GTSTR writing and the GPT compare match interrupt conflict, an interrupt may be generated after the GTSTR writing.
Therefore, stop the timer in the following order. Then, a compare match interrupt is not generated after the timer has been stopped, and the timer can be stopped in the safe way.

(1) Disable the interrupt request by the interrupt request enable registers (IER15 to IER18) of the ICU.
(2) Disable the interrupt request by the interrupt output setting register (GTINTAD) of the GPT.
(3) Clear the CSTn bit in GTSTR to 0.

18.9.4 Low-Power Consumption Setting when the LOCO Count Function is in Use

In the case when the GPT operation is stopped during the LOCO count operation by the module stop control register or standby control register and then restarted, first clear the LCCR.LCNTE bit to 0 to stop the LOCO count before the GPT operation is stopped. Then, set the LCCR.LCNTE bit to 1 to restart the LOCO count after the GPT operation is restarted. For details on the module stop control register and the standby control register, see section 9., Low Power Consumption.

19. Compare Match Timer (CMT)

The RX62T Group has two on-chip compare match timer (CMT) units (unit 0 and unit 1) each consisting of a two-channel 16-bit timer (i.e., a total of four channels). The CMT has a 16-bit counter, and can generate interrupts at set intervals.

19.1 Overview

Table 19.1 lists the specifications for the CMT.

Figure 19.1 shows a block diagram of the CMT (unit 0). A two-channel CMT constitutes a unit. Unit 0 and unit 1 are the same in terms of specifications.

Table 19.1 Specifications of CMT

Item	Description
Count clock	• Four internal clocks One clock from PCLK/8, PCLK/32, PCLK/128, and PCLK/512 can be selected individually for each channel.
Interrupt	A compare match interrupt can be requested individually for each channel.
Low power consumption facilities	Each unit can be placed in a module stop state.

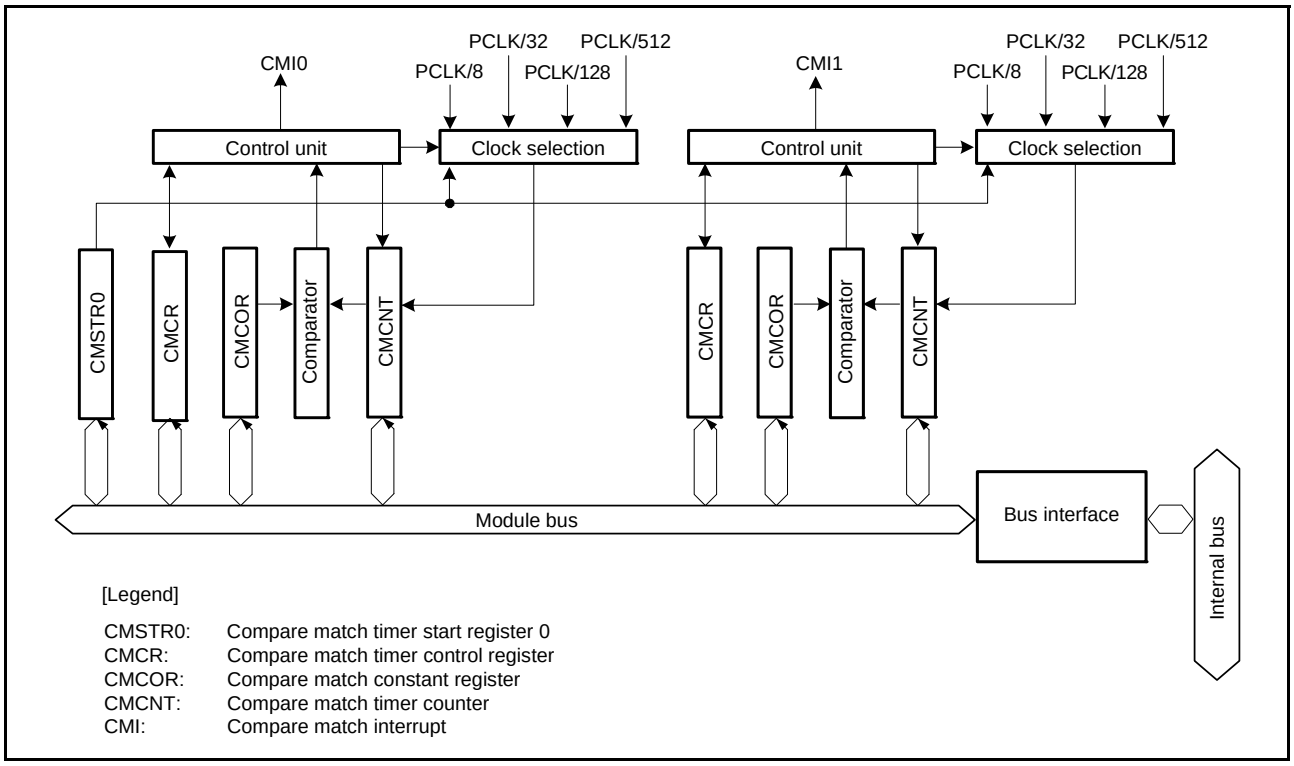


Figure 19.1 Block Diagram of CMT (Unit 0)

19.2 Register Descriptions

Table 19.2 lists the registers of the CMT.

Table 19.2 List of CMT Registers

Unit	Channel	Register Name	Symbol	Value after Reset	Address	Access Size
Unit 0	CMT	Compare match timer start register 0	CMSTR0	0000h	0008 8000h	16
	CMT0	Compare match timer control register	CMCR	00x0h	0008 8002h	16
		Compare match timer counter	CMCNT	0000h	0008 8004h	16
		Compare match timer constant register	CMCOR	FFFFh	0008 8006h	16
	CMT1	Compare match timer control register	CMCR	00x0h	0008 8008h	16
		Compare match timer counter	CMCNT	0000h	0008 800Ah	16
		Compare match timer constant register	CMCOR	FFFFh	0008 800Ch	16
Unit 1	CMT	Compare match timer start register 1	CMSTR1	0000h	0008 8010h	16
	CMT2	Compare match timer control register	CMCR	00x0h	0008 8012h	16
		Compare match timer counter	CMCNT	0000h	0008 8014h	16
		Compare match timer constant register	CMCOR	FFFFh	0008 8016h	16
	CMT3	Compare match timer control register	CMCR	00x0h	0008 8018h	16
		Compare match timer counter	CMCNT	0000h	0008 801Ah	16
		Compare match timer constant register	CMCOR	FFFFh	0008 801Ch	16

19.2.1 Compare Match Timer Start Register 0 (CMSTR0)

Address: 0008 8000h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	STR1	STR0
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	STR0	Count Start 0	0: CMT0.CMCNT count is stopped 1: CMT0.CMCNT count is started	R/W
b1	STR1	Count Start 1	0: CMT1.CMCNT count is stopped 1: CMT1.CMCNT count is started	R/W
b15 to b2	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

CMSTR0 selects whether the CMT0.CMCNT or CMT1.CMCNT counter operates or is stopped.

STR0 Bit (Count Start 0)

The STR0 bit specifies whether CMT0.CMCNT operates or is stopped.

STR1 Bit (Count Start 1)

The STR1 bit specifies whether CMT1.CMCNT operates or is stopped.

19.2.2 Compare Match Timer Start Register 1 (CMSTR1)

Address: 0008 8010h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	STR3	STR2
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	STR2	Count Start 2	0: CMT2.CMCNT count is stopped 1: CMT2.CMCNT count is started	R/W
b1	STR3	Count Start 3	0: CMT3.CMCNT count is stopped 1: CMT3.CMCNT count is started	R/W
b15 to b2	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

CMSTR1 selects whether the CMT2.CMCNT or CMT3.CMCNT counter operates or is stopped.

STR2 Bit (Count Start 2)

The STR2 bit specifies whether CMT2.CMCNT operates or is stopped.

STR3 Bit (Count Start 3)

The STR3 bit specifies whether CMT3.CMCNT operates or is stopped.

19.2.3 Compare Match Timer Control Register (CMCR)

Address: CMT0.CMCR 0008 8002h, CMT1.CMCR 0008 8008h,
CMT2.CMCR 0008 8012h, CMT3.CMCR 0008 8018h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	—	CMIE	—	—	—	CKS[1:0]		
Value after reset:	0	0	0	0	0	0	0	0	x	0	0	0	0	0	0	0

x: Undefined

Bit	Symbol	Bit Name	Description	R/W
b1, b0	CKS[1:0]	Clock Select	b1 b0 0 0: PCLK/8 0 1: PCLK/32 1 0: PCLK/128 1 1: PCLK/512	R/W
b5 to b2	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b6	CMIE	Compare Match Interrupt Enable	0: Compare match interrupt (CMIn) disabled 1: Compare match interrupt (CMIn) enabled	R/W
b7	—	Reserved	This bit is always read as undefined. The write value should always be 1.	R/W
b15 to b8	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

CMCR sets the clock used for counting up.

If data write to the CMCR register conflicts with the generation of a compare-match, data write to the CMCR register is ignored. For details, see section 19.5.4, Notes on Data Write to the Compare-Match Timer Control Register (CMCR).

CKS[1:0] Bits (Clock Select)

These bits select the count clock to be input to CMCNT from four internal clocks obtained by dividing the peripheral clock (PCLK).

When the STRn (n = 0 to 3) bit in CMSTRm (m = 0 or 1) is set to 1, CMCNT starts counting up on the count clock selected with bits CKS[1:0].

CMIE Bit (Compare Match Interrupt Enable)

The CMIE bit enables or disables compare match interrupt (CMIn) (n = 0 to 3) generation when CMCNT and CMCOR values match.

19.2.4 Compare Match Timer Counter (CMCNT)

Address: CMT0.CMCNT 0008 8004h, CMT1.CMCNT 0008 800Ah,
CMT2.CMCNT 0008 8014h, CMT3.CMCNT 0008 801Ah

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

CMCNT is a readable/writable up-counter to generate interrupt requests.

When a count clock is selected by bits CKS[1:0] in CMCR and the STRn (n = 0 to 3) bit in CMSTRm (m = 0 or 1) is set to 1, CMCNT starts counting up using the selected count clock.

When the value in CMCNT and the value in CMCOR match, CMCNT is cleared to 0000h. At the same time, a compare match interrupt (CMIn) (n = 0 to 3) is generated.

Do not set the CMCNT counter and the CMCOR register to the same value while the CMCNT counter counting operation is halted. For details, see section 19.5.5, Notes on the Compare-Match Timer Counter (CMCNT) and the Compare-Match Constant Register (CMCOR).

19.2.5 Compare Match Timer Constant Register (CMCOR)

Address: CMT0.CMCOR 0008 8006h, CMT1.CMCOR 0008 800Ch,
CMT2.CMCOR 0008 8016h, CMT3.CMCOR 0008 801Ch

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

CMCOR sets the interval up to a compare match with CMCNT.

Do not set the CMCNT counter and the CMCOR register to the same value while the CMCNT counter counting operation is halted. For details, see section 19.5.5, Notes on the Compare-Match Timer Counter (CMCNT) and the Compare-Match Constant Register (CMCOR).

19.3 Operation

19.3.1 Periodic Count Operation

When a count clock is selected by bits CKS[1:0] in CMCR and the STRn (n = 0 to 3) bit in CMSTRm (m = 0 or 1) is set to 1, CMCNT starts counting up using the selected count clock.

When the value in CMCNT and the value in CMCOR match, CMCNT is cleared to 0000h. At the same time, a compare match interrupt (CMIn) (n = 0 to 3) is generated. CMCNT then starts counting up again from 0000h. Figure 19.2 shows the operation of the CMCNT counter.

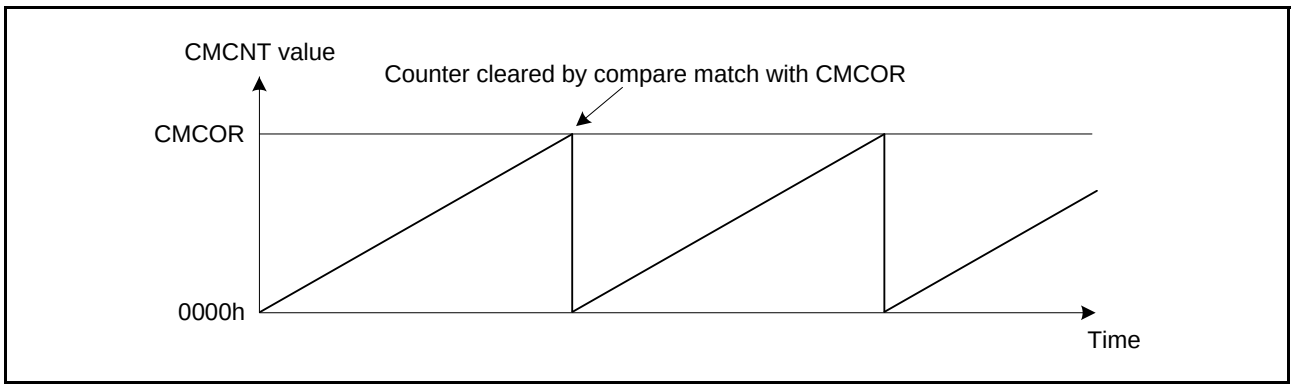


Figure 19.2 CMCNT Counter Operation

19.3.2 CMCNT Count Timing

One of four internal clocks (PCLK/8, PCLK/32, PCLK/128, and PCLK/512) obtained by dividing the peripheral clock (PCLK) can be selected as a count clock with the CKS[1:0] bits in CMCSR. Figure 19.3 shows the timing of CMCNT.

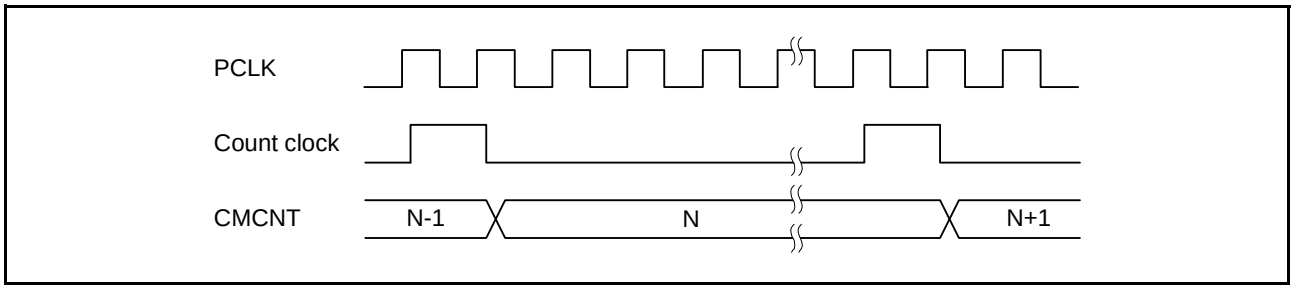


Figure 19.3 CMCNT Count Timing

19.4 Interrupts

19.4.1 Interrupt Sources

The CMT has channels and each of them to which a different vector address is allocated has a compare match interrupt (CMIn) (n = 0 to 3). When a compare match interrupt occurs, the corresponding interrupt request is output.
When the interrupt is used to activate a CPU interrupt, the priority of channels can be changed by the interrupt controller settings. For details, see section 11., Interrupt Controller (ICU).

Table 19.3 CMT Interrupt Sources

Name	Interrupt Sources	Interrupt Status Flag	DTC Activation
CMI0	Compare match between CMT0.CMCNT and CMT0.CMCOR	IR028.IR	Possible
CMI1	Compare match between CMT1.CMCNT and CMT1.CMCOR	IR029.IR	Possible
CMI2	Compare match between CMT2.CMCNT and CMT2.CMCOR	IR030.IR	Possible
CMI3	Compare match between CMT3.CMCNT and CMT3.CMCOR	IR031.IR	Possible

19.4.2 Timing of Compare Match Interrupt Generation

When CMCNT and CMCOR match, a compare match interrupt (CMIn) (n = 0 to 3) is generated.

A compare match signal is generated at the last state in which the values match (the timing when the CMCNT counter updates the matched count value). That is, after a match between CMCOR and CMCNT, the compare match signal is not generated until the next count clock.

Figure 19.4 shows the timing of the interrupt for a compare-match.

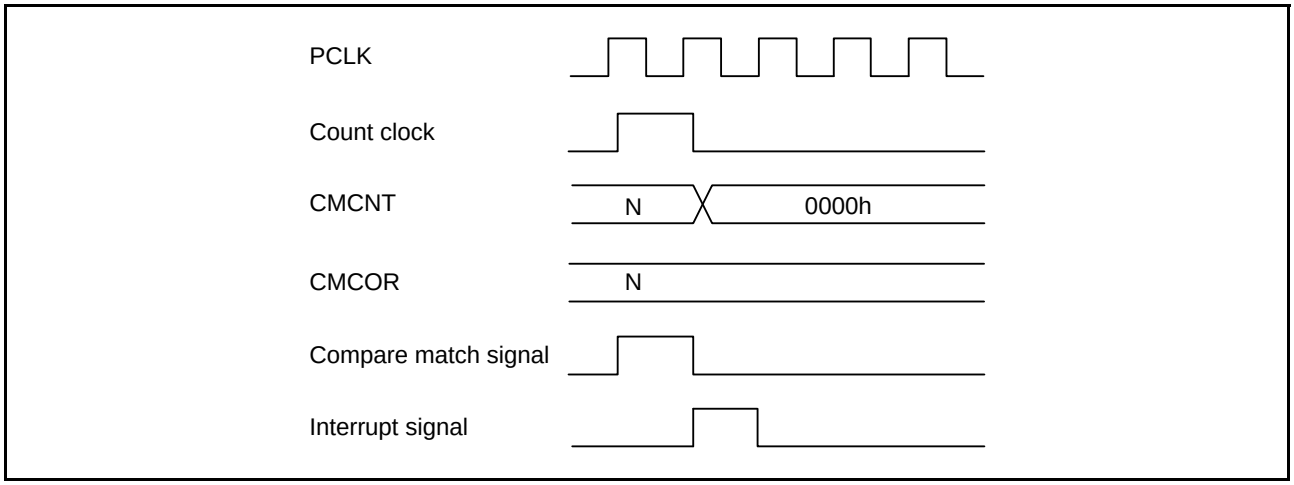


Figure 19.4 Timing of Generation of Compare Match Signal

19.5 Usage Notes

19.5.1 Setting the Module Stop Function

The CMT can be enabled or disabled using the module stop control register. The CMT is disabled by default. The registers can be accessed by canceling the module stop state. For details, see section 9., Low Power Consumption.

19.5.2 Conflict between Write and Compare-Match Processes of Compare Match Timer Counter (CMCNT)

When the compare match signal is generated while writing to CMCNT, clearing CMCNT has priority over writing to it. In this case, CMCNT is not written to. Figure 19.5 shows the timing to clear the CMCNT counter.

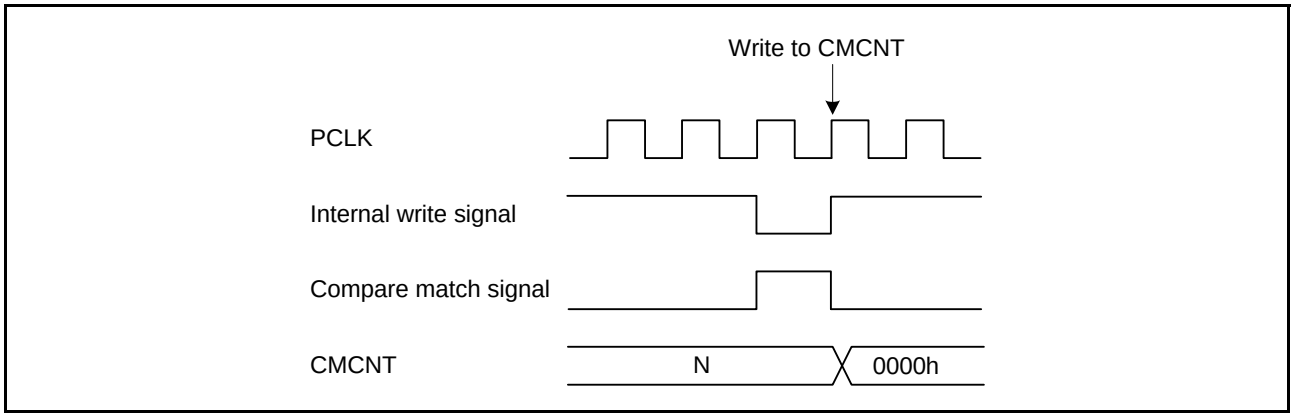


Figure 19.5 Conflict between Write and Compare Match Processes of CMCNT

19.5.3 Conflict between Write and Count-Up Processes of Compare Match Timer Counter (CMCNT)

Even when the count-up occurs while writing to CMCNT, the writing has priority over the count-up. In this case, the count-up is not performed. Figure 19.6 shows the timing to write the CMCNT counter.

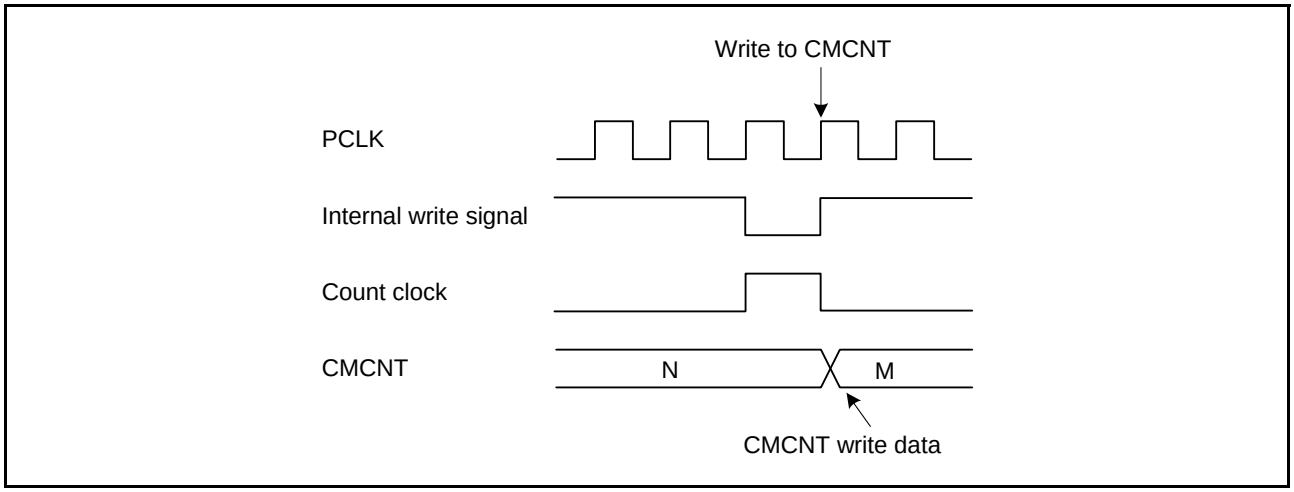


Figure 19.6 Conflict between Write and Count-Up Processes of CMCNT

19.5.4 Notes on Data Write to the Compare-Match Timer Control Register (CMCR)

If data write to the CMCR register conflicts with the generation of a compare-match, data write to the CMCR register is ignored. Therefore, write data to the CMCR register, then read the data from the CMCR register to confirm that the data is written correctly. If the data is not written correctly, write data to the CMCR register again.

Since undefined data is read from bit 7 in the CMCR register, comparison with the written data requires special care.

19.5.5 Notes on the Compare-Match Timer Counter (CMCNT) and the Compare-Match Constant Register (CMCOR)

Do not set the CMCNT counter and the CMCOR register to the same value while the CMCNT counter is halted. Otherwise, a compare-match occurs even while the counter is halted. At this time, if the compare-match interrupt enable bit (CMCR.CMIE) is set to 1 (enabled), a compare-match interrupt is generated.

Note that the CMCNT counter is automatically cleared to 0000h when a compare-match with the CMCOR register value occurs regardless of whether a compare-match interrupt is disabled or enabled.

20. Watchdog Timer (WDT)

The watchdog timer (WDT) is an 8-bit timer that outputs an overflow signal (WDTOVF#) if a system crash prevents the CPU from writing to the timer counter, thus allowing it to overflow. At the same time, the WDT can internally reset the LSI.

When this watchdog function is not needed, the WDT can be used as an interval timer. In interval timer operation, an interval timer interrupt is generated each time the counter overflows.

20.1 Overview

Table 20.1 lists the specifications of the WDT.

Figure 20.1 shows a block diagram of the WDT.

Table 20.1 Specifications of WDT

Item	Specifications
Count clocks	PCLK/4, PCLK/64, PCLK/128, PCLK/512, PCLK/2048, PCLK/8192, PCLK/32768, and PCLK/131072
Number of channels	8 bits x 1 channel
Count clear	Write to TCNT
Operating modes	Switchable between watchdog timer mode and interval timer mode
Watchdog timer mode	Outputs a WDTOVF# signal when the counter overflows. Selectable whether or not to internally reset the LSI at the same time.
Interval timer mode	Generates an interval timer interrupt (WOVI) when the counter overflows.

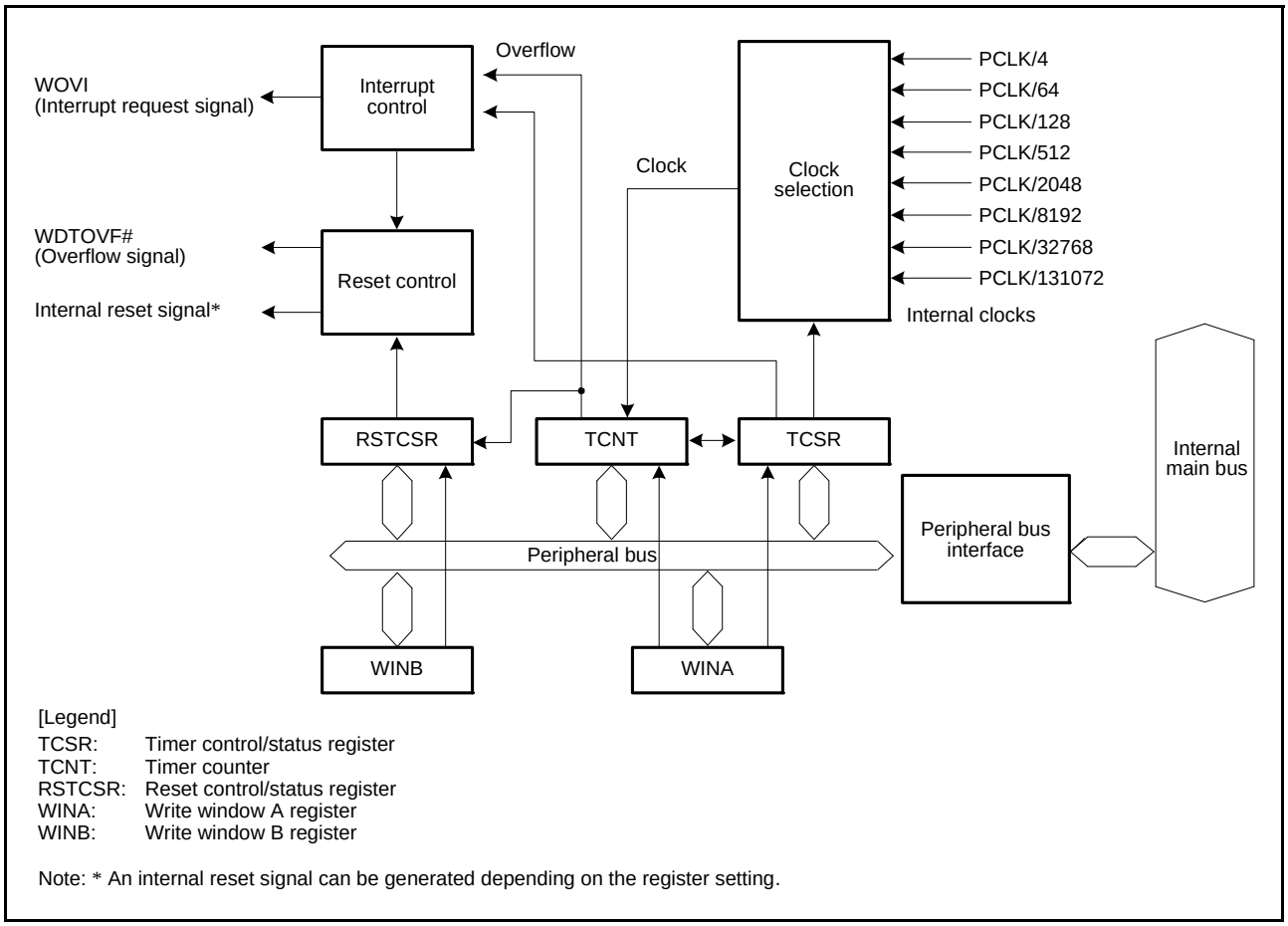


Figure 20.1 Block Diagram of WDT

Table 20.2 shows the input/output pin used for the WDT.

Table 20.2 Pin Configuration

Pin Name	I/O	Description
WDTOVF#	Output	Outputs a counter overflow signal in watchdog timer mode.

20.2 Register Descriptions

Table 20.3 lists the registers of the WDT.

Table 20.3 WDT Registers

Register Name	Symbol	Value after Reset	Address	Access Size
Timer control/status register	TCSR	x8h	0008 8028h*1	8
Timer counter	TCNT	00h	0008 8029h*1	8
Reset control/status register	RSTCSR	1Fh	0008 802Bh*1	8
Write window A register	WINA	—	0008 8028h*2	16
Write window B register	WINB	—	0008 802Ah*2	16

Note 1. Read-only register
Note 2. Write-only register

20.2.1 Timer Counter (TCNT)

Address: 0008 8029h

	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	0	0	0	0	0	0	0	0

TCNT is an 8-bit up-counter for the internal clock.

TCNT is initialized to 00h when the TME bit in TCSR is set to 0.

To read this counter, use 8-bit access.

To write to this counter, write data in WINA by 16-bit access.

For details, see section 20.5.1, Notes on Register Access.

20.2.2 Timer Control/Status Register (TCSR)

Address: 0008 8028h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	TMS	TME	—	—	CKS[2:0]		
Value after reset:	x	0	0	1	1	0	0	0

x: Undefined

Bit	Symbol	Bit Name	Description	R/W
b2 to b0	CKS[2:0]	Clock Select	b2 b0 0 0 0: PCLK/4 (cycle: 20.4 μs) 0 0 1: PCLK/64 (cycle: 326.4 μs) 0 1 0: PCLK/128 (cycle: 652.8 μs) 0 1 1: PCLK/512 (cycle: 2.6 ms) 1 0 0: PCLK/2048 (cycle: 10.4 ms) 1 0 1: PCLK/8192 (cycle: 41.8 ms) 1 1 0: PCLK/32768 (cycle: 167.1 ms) 1 1 1: PCLK/131072 (cycle: 668.5 ms) Note: The overflow cycle for PCLK = 50 MHz is indicated in parentheses.	R/W
b4, b3	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W
b5	TME	Timer Enable	0: TCNT stops counting and is initialized to 00h. 1: TCNT starts counting.	R/W
b6	TMS	Timer Mode Select	0: Interval timer mode When TCNT overflows, an interval timer interrupt (WOVI) is requested. 1: Watchdog timer mode When TCNT overflows, WDTOVF# is output.	R/W
b7	—	Reserved	If read, an undefined value will be read. The write value should always be 1.	R/W

TCSR selects the clock source to be input to TCNT, and the timer mode.

To read this register, use 8-bit access.

To write to this register, write data to WINA by 16-bit access.

For details, see section 20.5.1, Notes on Register Access.

CKS[2:0] Bits (Clock Select)

These bits select the clock source to be input to TCNT.

TME Bit (Timer Enable)

Selects whether TCNT starts or stops counting. When this bit is set to 1, TCNT starts counting. When this bit is cleared to 0, TCNT stops counting and is initialized to 00h.

TMS Bit (Timer Select)

Selects whether the WDT is used as a watchdog timer or interval timer.

20.2.3 Reset Control/Status Register (RSTCSR)

Address: 0008 802Bh

	b7	b6	b5	b4	b3	b2	b1	b0
	WOVF	RSTE	—	—	—	—	—	—
Value after reset:	0	0	0	1	1	1	1	1

Bit	Symbol	Bit Name	Description	R/W
b4 to b0	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W
b5	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b6	RSTE	Reset Enable	0: The LSI is not reset internally when TCNT overflows in watchdog timer mode. (TCNT and TCSR of the WDT are reset.) 1: The LSI is internally reset when TCNT overflows in watchdog timer mode.	R/W
b7	WOVF	Watchdog Timer Overflow Flag	0: TCNT has not overflowed in watchdog timer mode. 1: TCNT has overflowed in watchdog timer mode.	R/(W)*

Note : * Only 0 can be written to this bit, to clear the flag.

RSTCSR controls the generation of the internal reset signal when TCNT overflows, and selects the type of internal reset signal.

RSTCSR is initialized to 1Fh by a reset signal from the RES# pin or a deep software standby reset, but not by the WDT internal reset signal caused by a WDToverflow.

To read this register, use 8-bit access.

To write to this register, write data in WINB by 16-bit access.

For details, see section 20.5.1, Notes on Register Access.

RSTE Bit (Reset Enable)

Selects whether or not this LSI is internally reset when TCNT overflows in watchdog timer mode.

WOVF Flag (Watchdog Timer Overflow)

Indicates that TCNT overflows in watchdog timer mode. This bit cannot be set to 1 in interval timer mode.

[Setting condition]

- When TCNT overflows (changed form FFh to 00h) in watchdog timer mode

[Clearing condition]

- Reading RSTCSR when WOVF = 1, and then writing 0 to WOVF

20.2.4 Write Window A Register (WINA)

Address: 0008 8028h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

WINA is a write-only register for writing to TCNT and TCSR.

The writing method varies between TCNT and TCSR. For details, see section 20.5.1, Notes on Register Access.

To write to this register, use 16-bit access.

20.2.5 Write Window B Register (WINB)

Address: 0008 802Ah

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

WINB is a write-only register for writing to RSTCSR.

The writing method varies between writing 0 to the WOVF flag in RSTCSR and writing the RSTE bit in RSTCSR. For details, see section 20.5.1, Notes on Register Access. To write to this register, use 16-bit access.

20.3 Operation

20.3.1 Watchdog Timer Mode

To use the WDT in watchdog timer mode, set the TCSR.TMS bit to 1 (watchdog timer mode) and the TCSR.TME bit to 1 (TCNT starts counting).

During watchdog timer operation, if TCNT overflows without being rewritten because of a system crash or another error, the WDTOVF# signal is output. This ensures that TCNT does not overflow while the system is operating normally. Software must prevent TCNT overflows by rewriting the TCNT value (normally 00h is written) before overflow occurs. This WDTOVF# signal can be used to reset the LSI internally in watchdog timer mode.

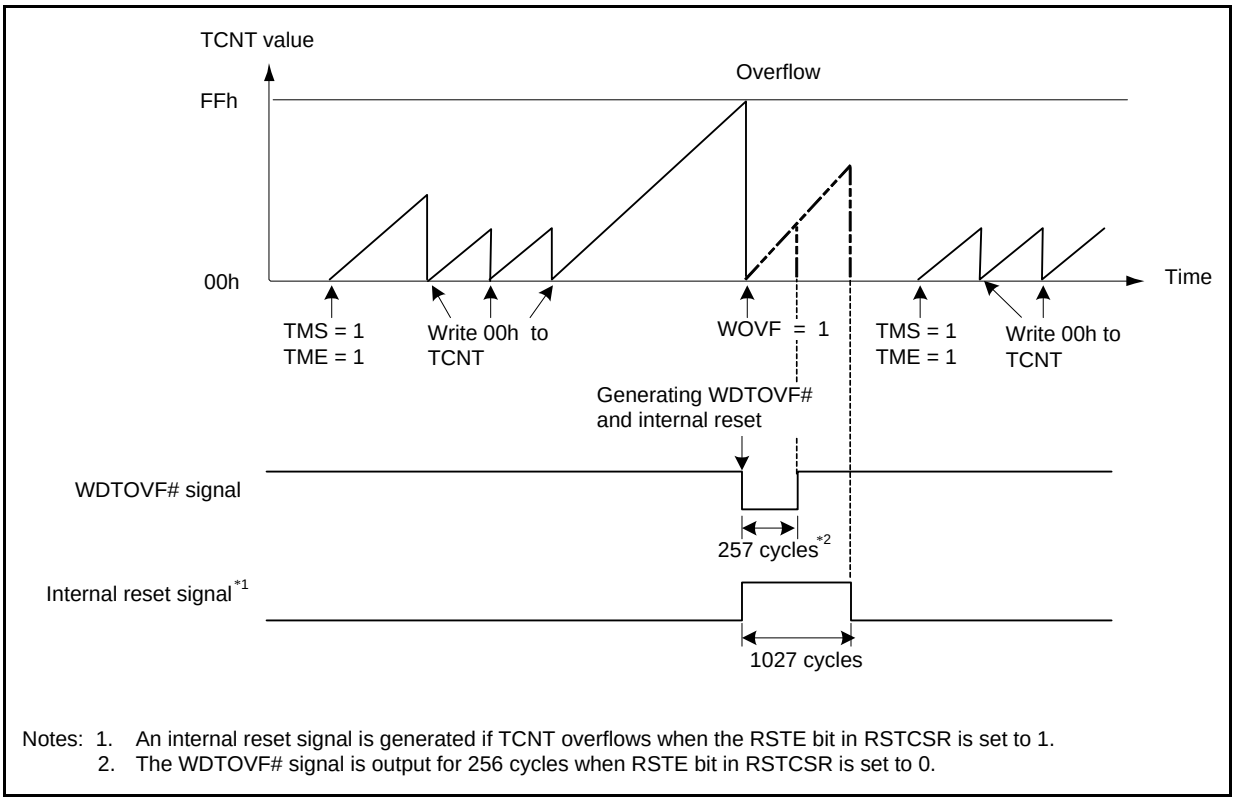
If TCNT counter overflows in the watchdog timer mode, the RSTCSR.WOVF bit is set to 1. In addition, if TCNT counter overflows while the RSTCSR.RSTE bit is set to 1, a signal that resets the LSI internally is generated as the same time as the WDTOVF# signal is output. If a reset caused by a signal input to the RES# pin occurs at the same time as a reset caused by a WDT overflow, the RES# pin reset has priority and the WOVF flag in RSTCSR is cleared to 0.

The WDTOVF# signal is output for 257 cycles of PCLK when RSTE = 1, and for 256 cycles of PCLK when RSTE = 0. The internal reset signal is output for 1027 cycles of PCLK.

When RSTE = 1, an internal reset signal is generated. Since the system clock control register (SCKCR) is initialized, the multiplication ratio of PCLK becomes the initial value.

When RSTE = 0, an internal reset signal is not generated. Neither SCKCR nor the multiplication ratio of PCLK is changed.

When TCNT overflows in watchdog timer mode, the WOVF flag is set to 1. If TCNT overflows when the RSTE bit is set to 1, an internal reset signal is generated for the entire RX62T.



Notes: 1. An internal reset signal is generated if TCNT overflows when the RSTE bit in RSTCSR is set to 1.
2. The WDTOVF# signal is output for 256 cycles when RSTE bit in RSTCSR is set to 0.

Figure 20.2 Operation in Watchdog Timer Mode

20.3.2 Interval Timer Mode

To use the WDT as an interval timer, set the TCSR.TMS bit to 0 (interval timer mode) and the TCSR.TME bit to 1 (TCNT starts counting).

When the WDT is used as an interval timer, an interval timer interrupt (WOVI) is generated each time TCNT overflows. Therefore, an interrupt can be generated at intervals.

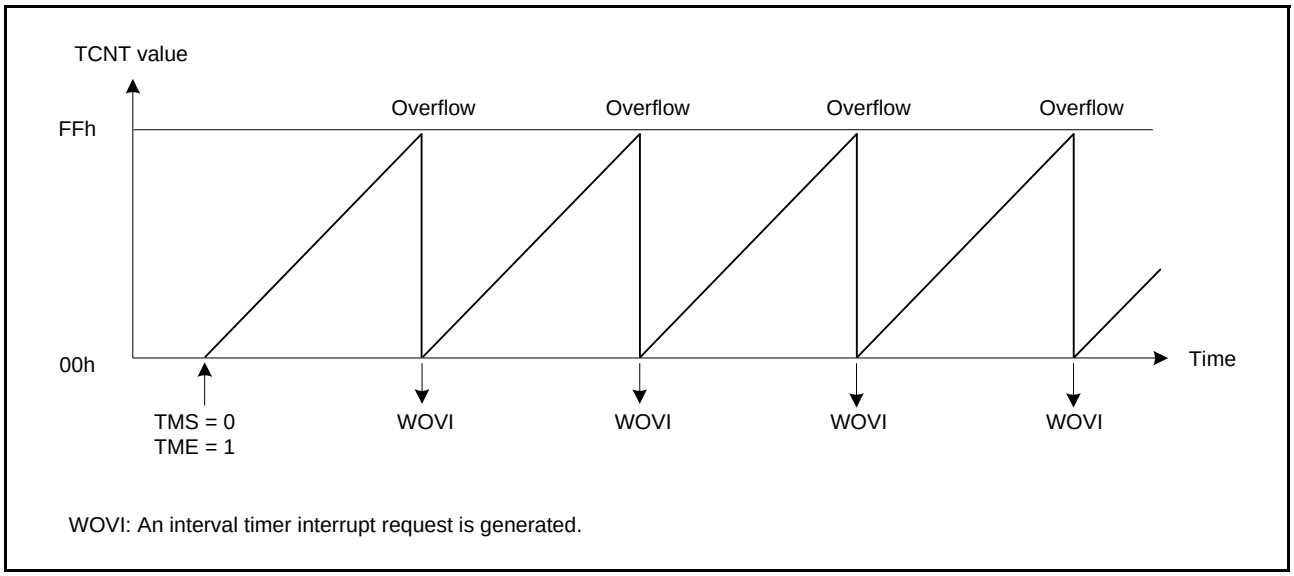


Figure 20.3 Operation in Interval Timer Mode

20.4 Interrupt Source

During interval timer mode operation, a TCNT overflow generates an interval timer interrupt (WOVI). For details, see section 11., Interrupt Controller (ICU).

Table 20.4 WDT Interrupt Source

Name	Interrupt Source	Interrupt Status Flag	DTC Activation
WOVI	TCNT overflow	IR096.IR	Not possible

20.5 Usage Notes

20.5.1 Notes on Register Access

The watchdog timer's TCNT, TCSR, and RSTCSR differ from other registers in being more difficult to write to.

(1) Writing to TCNT Counter, TCSR Register, and RSTCSR Register

When writing to TCNT and TCSR, be sure to use a word transfer instruction to the write window A register (WINA) (00088028h). For writing, TCNT and TCSR are assigned to the same address. Accordingly, perform data transfer as shown in Figure 20.4.

To write to TCNT, set 5Ah in the upper byte and data in the lower byte, and perform data transfer to TCNT.

To write to TCSR, set A5h in the upper byte and data in the lower byte, and perform data transfer to TCSR.

When writing to RSTCSR, use a word transfer instruction to the write window B register (WINB) (0008802Ah).

The method of writing 0 to the WOVF flag in RSTCSR differs from that of writing to the RSTE bit in RSTCSR. Perform data transfer as shown in Figure 20.4.

To write 0 to the WOVF flag, set A5h in the upper byte and 00h in the lower byte and write data in 16 bits, as shown in Figure 20.4. This writing has no effect on the RSTE bit.

To write to the RSTE bit, set 5Ah in the upper byte and the RSTCSR register write data in the lower byte and write data in 16 bits, as shown in Figure 20.4. This writing has no effect on the WOVF flag.

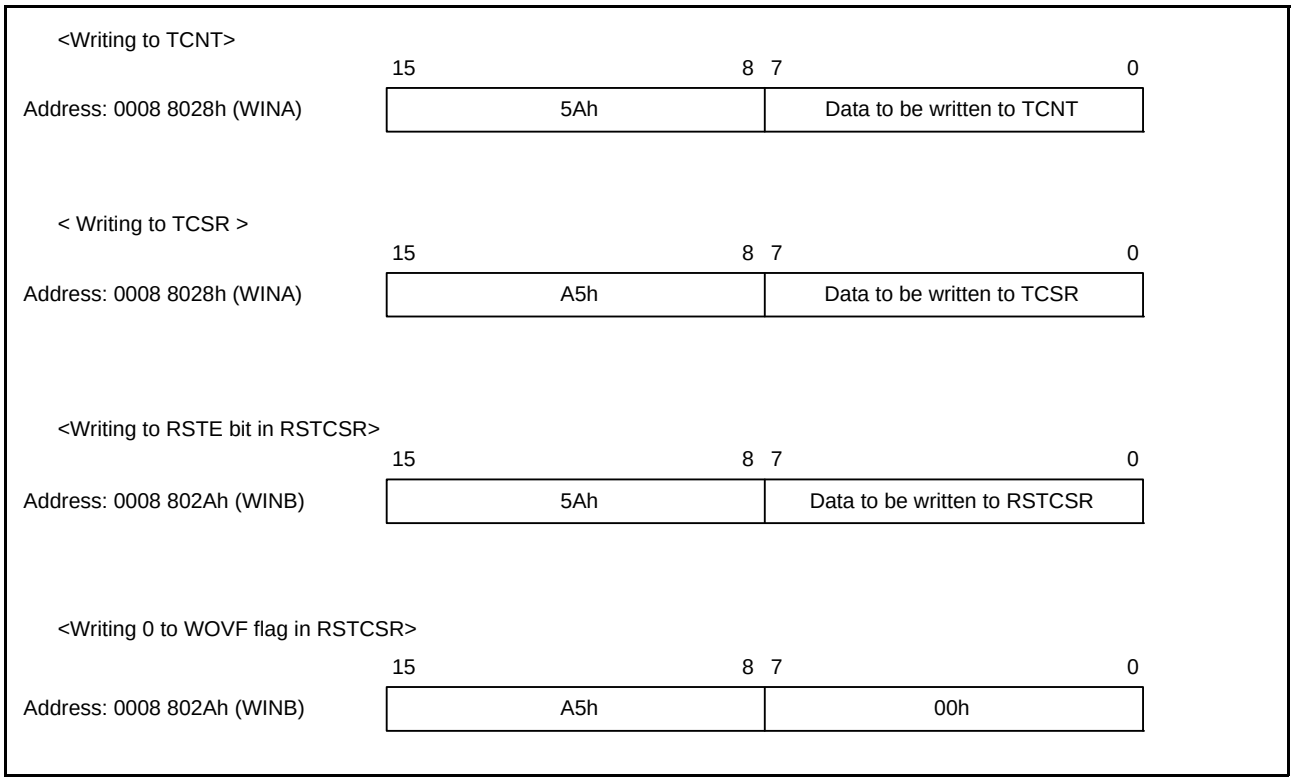


Figure 20.4 Writing to TCNT, TCSR, and RSTCSR

(2) Reading from TCNT Counter, TCSR Register, and RSTCSR Register

These counter and registers can be read from in the same way as other registers.

TCSR is assigned to address 00088028h, TCNT to address 00088029h, and RSTCSR to address 0008802Ah. For reading, use 8-bit access.

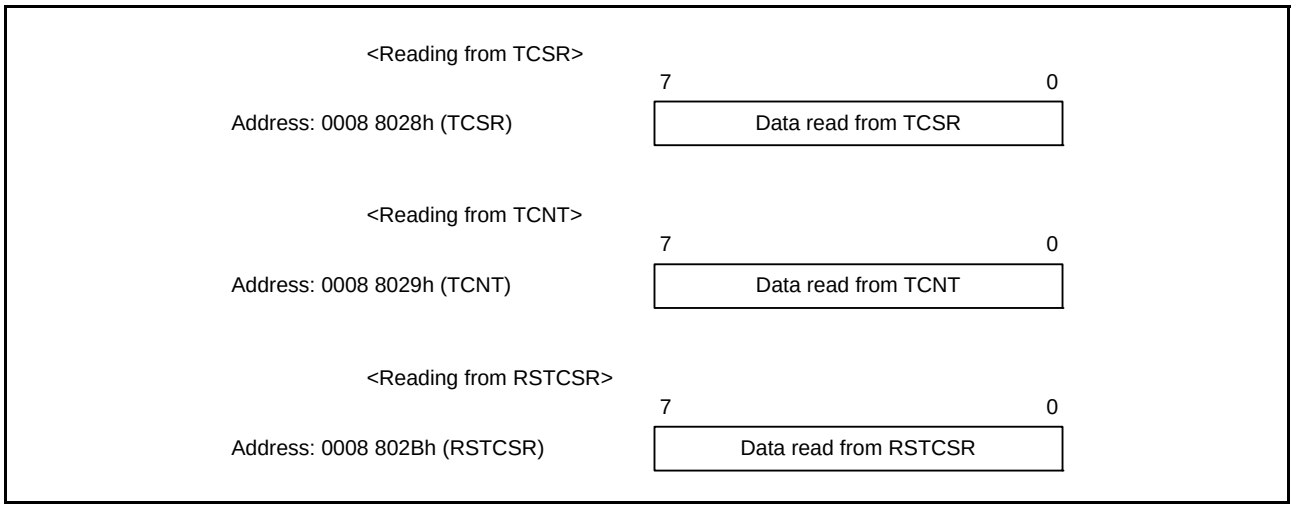


Figure 20.5 Reading from TCNT, TCSR, and RSTCSR

20.5.2 Conflict between Timer Counter (TCNT) Write and Increment

If a TCNT clock pulse is generated during a TCNT write cycle, the write takes priority and the timer counter is not incremented. Figure 20.6 shows this operation.

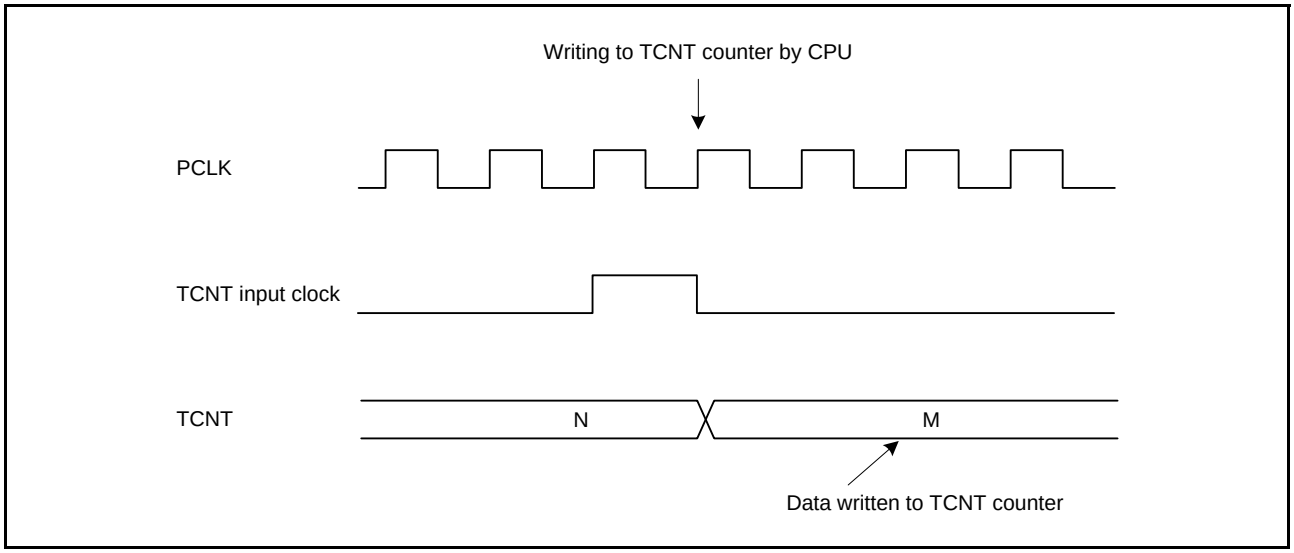


Figure 20.6 Conflict between TCNT Write and Increment

20.5.3 Changing Values of Bits CKS[2:0]

If bits CKS[2:0] bits in TCSR are written to while the WDT is operating, errors could occur in the incrementation. The watchdog timer must be stopped (by clearing the TME bit in TCSR to 0) before the values of CKS[2:0] bits in TCSR are changed.

20.5.4 Switching between Watchdog Timer Mode and Interval Timer Mode

If the timer mode is switched from watchdog timer mode to interval timer mode while the watchdog timer is operating, errors could occur in the operation. The watchdog timer must be stopped (by clearing the TME bit in TCSR to 0) before switching the timer mode.

20.5.5 Internal Reset in Watchdog Timer Mode

The RX62T is not reset internally if TCNT overflows while the RSTE bit in RSTCSR is cleared to 0 during watchdog time mode operation, but TCNT and the TCSR of the watchdog timer are reset.

TCNT, TCSR, and RSTCSR cannot be written to while the WDTOVF# signal is low. Also note that a read of the WOVF flag in RSTCSR is not recognized during this period. To clear the WOVF flag, therefore, read RSTCSR after the WDTOVF# signal goes high, then write 0 to the WOVF flag.

20.5.6 System Reset by WDTOVF# Signal

If the WDTOVF# signal is input to the RES# pin, the RX62T will not be initialized correctly. Make sure that the WDTOVF# signal is not input logically to the RES# pin. To reset the entire system by means of the WDTOVF# signal, use a circuit like that shown in Figure 20.7.

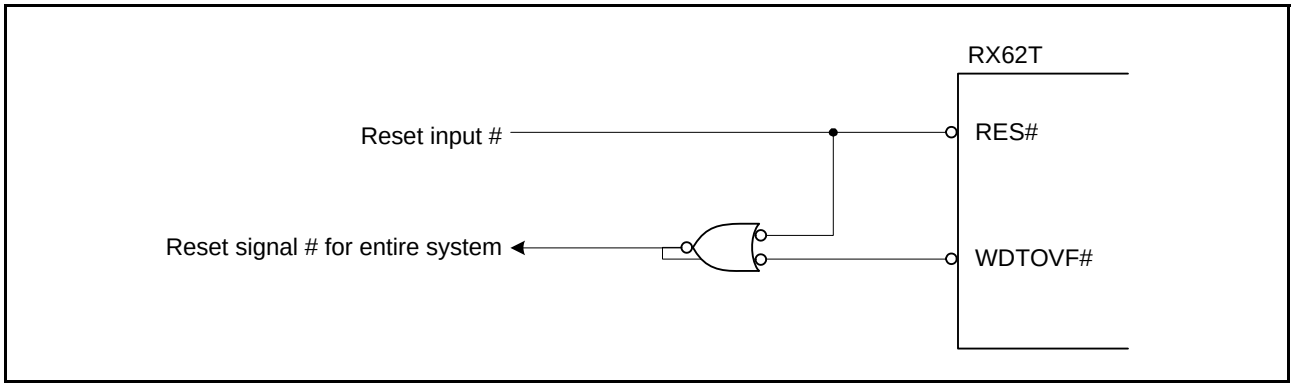


Figure 20.7 Circuit for System Reset by WDTOVF# Signal (Example)

20.5.7 Transition to Watchdog Timer Mode or Software Standby Mode

When the WDT operates in watchdog timer mode, a transition to software standby mode is not made even when the WAIT instruction is executed when the software standby bit (SSBY in SBYCR) in the standby control register is set to 1. Instead, a transition to sleep mode or all-module clock-stop mode is made.

To transit to software standby mode, the WAIT instruction must be executed after halting the watchdog timer (clearing the TME bit in TCSR to 0).

When the WDT operates in interval timer mode, a transition to software standby mode is made through execution of the WAIT instruction when the SSBY bit is set to 1. For details, see section 9., Low Power Consumption.

21. Independent Watchdog Timer (IWDT)

The independent watchdog timer (IWDT) is a watchdog timer for use independently of the conventional watchdog timer, which is for detecting programs entering runaway execution and system crashes.

The IWDT incorporates a 14-bit down-counter and resets the system if counting leads to an underflow of the value in the counter. The IWDT also has a refresh facility.

Note: • The value in the IWDT must be refreshed before the counter underflows. For details, see section 21.3.3, Control of Refreshing

21.1 Overview

The specifications of the IWDT are given in Table 21.1. Figure 21.1 is a block diagram of the IWDT.

Table 21.1 Specifications of the IWDT

Item	Specifications
Clock for counting	IWDTCLK, IWDTCLK/16, IWDTCLK/32, IWDTCLK/64, IWDTCLK/128, IWDTCLK/256
Counter operation	Counting down by a 14-bit down-counter
Conditions for starting the counter	Counting can be started by refreshing the down-counter (write FFh after 00h has been written to the IWDTRR register).
Conditions for stopping the counter	• Pin reset (the down-counter and other registers return to their initial values) • Generation of an underflow
Reset-output sources of the IWDT	Underflow of the down-counter
Reading the value of the IWDT counter	The value reached in counting by the down-counter can be read out from a register (the IWDTSR).

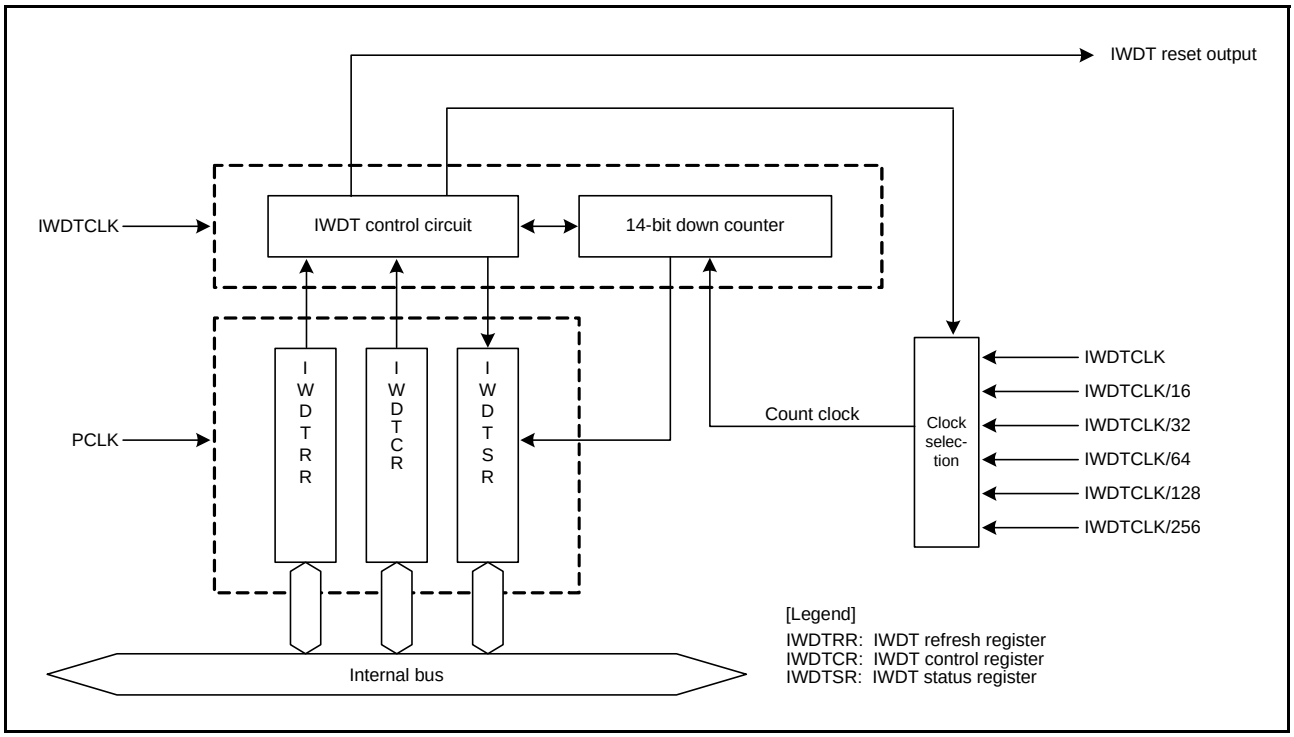


Figure 21.1 Block Diagram of the IWDT

21.2 Register Descriptions

Table 21.2 lists the registers of the IWDT.

Table 21.2 IWDT Registers

Register Name	Symbol	Value after Reset	Address	Access Size
IWDT refresh register	IWDTRR	FFh	0008 8030h	8
IWDT control register	IWDTCR	3303h	0008 8032h	16
IWDT status register	IWDTSR	0000h	0008 8034h	16

21.2.1 IWDT Refresh Register (IWDTRR)

Address: 0008 8030h

	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	1	1	1	1	1	1	1	1

IWDTRR refreshes the down-counter of the IWDT.

The down-counter of the IWDT is refreshed by writing 00h and then writing FFh to the IWDTRR (refreshing). After the counter has been refreshed, it starts counting down from the value selected by the TOPS[1:0] bits in the IWDT control register (IWDTCR).

In addition, when the first time the counter is refreshed after the release from the reset state, it starts counting down from the value selected by the TOPS[1:0] bits in IWDTCR.

Writing a value other than FFh after 00h invalidates the writing of 00h. To enable refreshing of the counter, 00h must be written to this register again, and this must be followed by writing of FFh.

Although reading the register after the writing of 00h will produce the value 00h, reading the register after writing any value other than 00h will always produce the value FFh.

21.2.2 IWDT Control Register (IWDTCR)

Address: 0008 8032h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	CKS[3:0]				—	—	TOPS[1:0]	
Value after reset:	0	0	1	1	0	0	1	1	0	0	0	0	0	0	1	1

Bit	Symbol	Bit Name	Description	R/W
b1, b0	TOPS[1:0]	Time-out Period Selection	b1 b0 0 0: 1024 cycles (03FFh) 0 1: 4096 cycles (0FFFh) 1 0: 8192 cycles (1FFFh) 1 1: 16384 cycles (3FFFh)	R/W
b3, b2	—	Reserved	These bits are read as 0. The write value should be 0.	R/W
b7 to b4	CKS[3:0]	Clock Selection	b7 b4 0 0 – –: IWDTCLK 0 1 0 0: IWDTCLK/16 0 1 0 1: IWDTCLK/32 0 1 1 0: IWDTCLK/64 0 1 1 1: IWDTCLK/128 1 – – –: IWDTCLK/256	R/W
b9, b8	—	Reserved	These bits are read as 1. The write value should be 1.	R/W
b11, b10	—	Reserved	These bits are read as 0. The write value should be 0.	R/W
b13, b12	—	Reserved	These bits are read as 1. The write value should be 1.	R/W
b15, b14	—	Reserved	These bits are read as 0. The write value should be 0.	R/W

IWDTCR specifies the time-out period for the underflow of the down-counter, and count clock.

Writing to the IWDTCR is only possible once during the period between release from the reset state and the first time the counter is refreshed. Writing to the IWDTCR is not possible after a refresh operation; furthermore, writing to the IWDTCR two or more times is not possible. This is because writing to the IWDTCR has been locked.

The writing to IWDTCR is unlocked by the reset source of the IWDT. With other reset sources, writing to the IWDTCR is not unlocked. For details, see section 6., Resets.

TOPS[1:0] Bits (Time-out Period Selection)

The TOPS[1:0] bits select the time-out period (period until the down-counter underflows) among 1024, 4096, 8192, or 16384 cycles, with taking the count clock specified by the CKS[3:0] bits as one cycle.

The combination of the settings of the CKS[3:0] and TOPS[1:0] bits determines the time (in cycles of the IWDTCLK) for the counter to underflow after being refreshed.

The relations between the settings of the CKS[3:0] and TOPS[1:0] bits, and the number of cycles of the IWDTCLK are shown in Table 21.3.

Table 21.3 Settings and Time-out Periods

CKS[3:0]				TOPS[1:0]		Count Clock	Time-out Period (Number of Cycles)	Cycles of the IWDTCLK Signal
0	0	—	—	0	0	IWDTCLK	1024	1024
				0	1		4096	4096
				1	0		8192	8192
				1	1		16384	16384
0	1	0	0	0	0	IWDTCLK/16	1024	16384
				0	1		4096	65536
				1	0		8192	131072
				1	1		16384	262144
0	1	0	1	0	0	IWDTCLK/32	1024	32768
				0	1		4096	131072
				1	0		8192	262144
				1	1		16384	524288
0	1	1	0	0	0	IWDTCLK/64	1024	65536
				0	1		4096	262144
				1	0		8192	524288
				1	1		16384	1048576
0	1	1	1	0	0	IWDTCLK/128	1024	131072
				0	1		4096	524288
				1	0		8192	1048576
				1	1		16384	2097152
1	—	—	—	0	0	IWDTCLK/256	1024	262144
				0	1		4096	1048576
				1	0		8192	2097152
				1	1		16384	4194304

CKS[3:0] Bits (Clock Selection)

These bits select the count clock for down counting among IWDTCLK, IWDTCLK/16, IWDTCLK/32, IWDTCLK/64, IWDTCLK/128, or IWDTCLK/256. In combination with the setting of the TOPS[1:0] bits, a counting period between 1024 and 4194304 cycles of the IWDTCLK signal is selected for the IWDT.

21.2.3 IWDT Status Register (IWDTSR)

Address: 0008 8034h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	UNDFF	CNTVAL [13:0]													
Value after reset:	0	0	1	1	0	0	1	1	0	0	0	0	0	0	1	1

Bits	Symbol	Name	Function	R/W
b13 to b0	CNTVAL [13:0]	Down-Counter	Value counted by the down-counter	R
b14	UNDFF	Underflow Flag	1: Underflow 0: No underflow	R/W
b15	—	Reserved	This bit is always read as 0. The write value should be 0.	R/W

IWDTSR checks the counter value of the down-counter, and the generation state of the underflow.

IWDTSR is initialized by the reset source of the IWDT. With other reset sources, IWDTSR is not initialized. For details, see section 6., Resets.

CNTVAL[13:0] Bits (Down-Counter)

These bits can be read to confirm the value of the down-counter.

UNDFF Flag (Underflow Flag)

This bit can be read to confirm the state of the down-counter in terms of whether or not an underflow has occurred.

The value "1" indicates that the down-counter has underflowed. The value "0" indicates that the down-counter has not underflowed.

Clear the UNDFF bit by writing "0" to it. Writing "1" has no effect.

21.3 Description of Operation

21.3.1 Count Operation of the Down-Counter

Settings for the count clock and the time-out period are made in the IWDTCR after release from the reset state. Refreshing the down-counter then starts it counting down from the value selected by the setting of the IWDTCR.TOPS[1:0] bits.

After that, as long as the program continues in normal operation, the value in the counter is re-set when the counter is refreshed, and counting down continues. The IWDT does not output the reset signal as long as this continues. However, if the down-counter underflows because refreshing the down-counter is not possible due to the program having entered crashed execution, the IWDT outputs the reset signal.

After assertion of the reset signal, the down-counter is initialized (all bits cleared to "0") and kept in that state. After the system has been re-booted, counting down is again started by refreshing the counter.

An example of operation under the below conditions is shown in Figure 21.2.

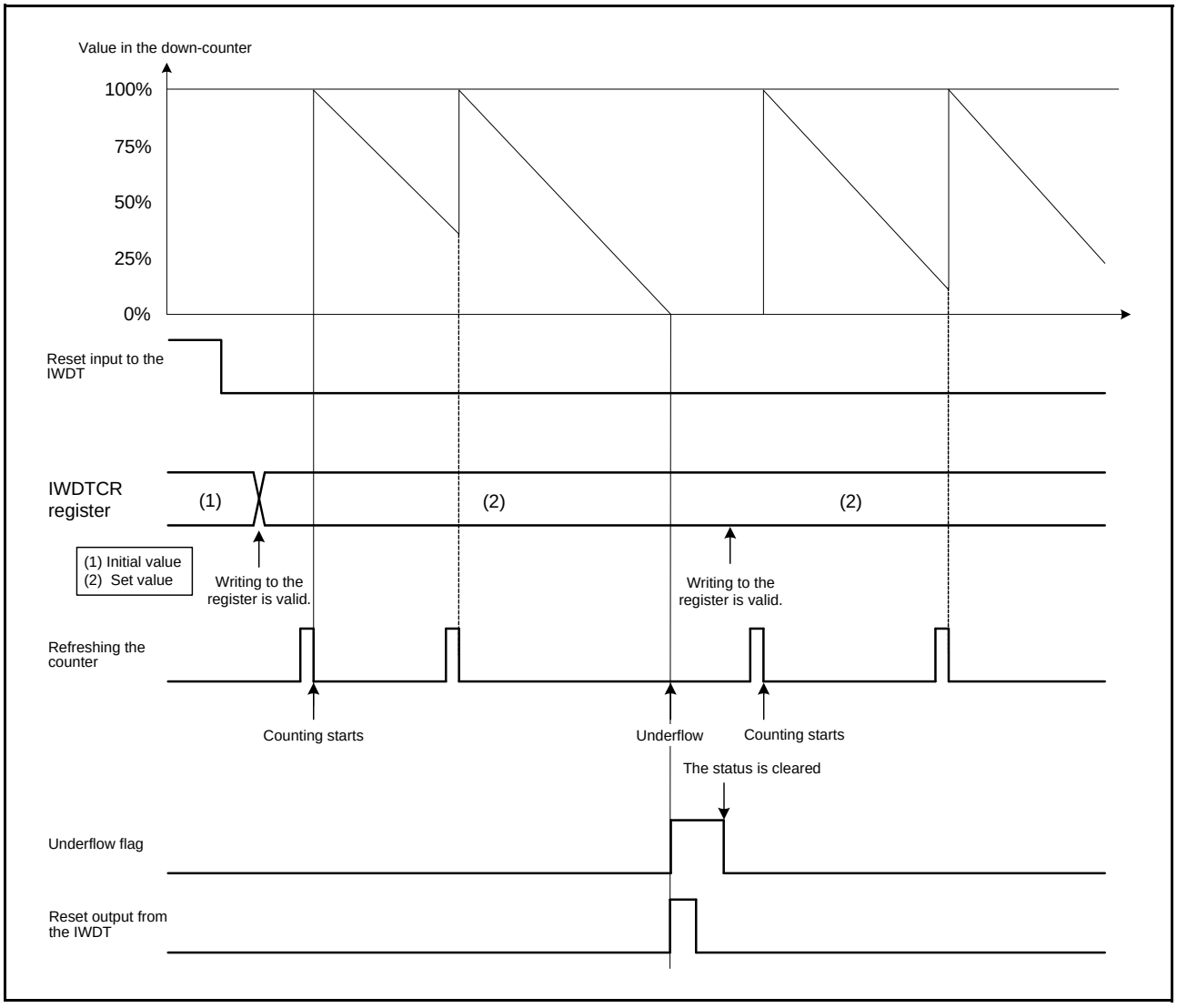


Figure 21.2 Example of Down-Counter Operation

21.3.2 Control over Writing to the IWDT Control Register (IWDTCR)

Writing to the IWDTCR is only possible for once after the reset state is canceled.

Writing to the IWDTCR makes the value of the internal register-lock signal of the IWDT become "1", locking the IWDTCR against subsequent attempts at writing.

The writing to IWDTCR is unlocked by the reset source of the IWDT. With other reset sources, writing to the IWDTCR is not unlocked. For details, see section 6., Resets.

Figure 21.3 is a chart of the waveforms in response to writing to the IWDTCR.

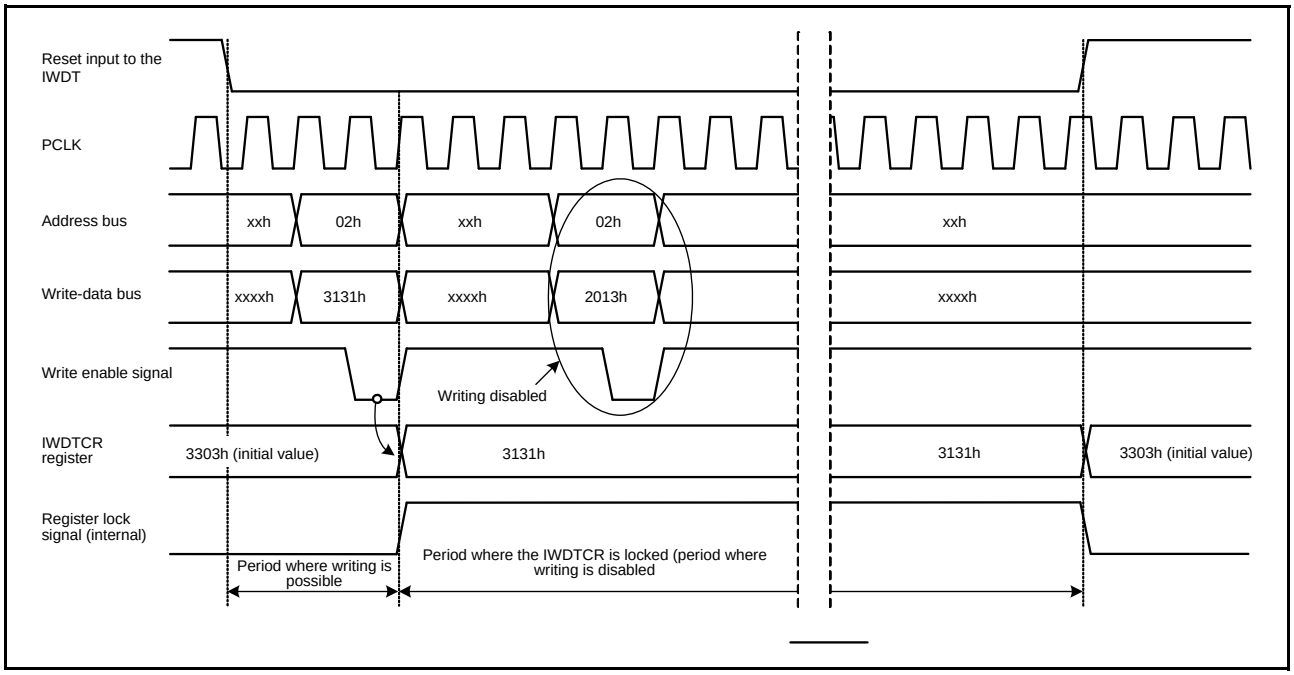


Figure 21.3 Control Waveforms in Response to Writing to the IWDTCR

21.3.3 Control of Refreshing

The IWDT starts operation (start of the down-counter) or the down-counter is refreshed by writing the values 00h and then FFh to the IWDT refresh register (IWDTRR). Write operations other than these (in order) are invalid. After invalid writing, correct refreshing is performed by writing 00h and then FFh to the IWDT refresh register (IWDTRR).

Though writing 00h → 00h is invalid, if FFh is written after that, writing 00h → FFh will be valid. Thus, writing 00h00hFFh is valid. Moreover, if the first writing value is not 00h, writing will be valid if the operation contains the set of writing 00h → FFh.

Sample sequences of writing that are invalid for refreshing the counter

- 23h (a value other than 00h) → FFh
- 00h → 54h (a value other than FFh)
- 00h → AAh (a value other than FFh) FFh

After writing of FFh to the IWDTRR register, refreshing the down-counter requires up to four cycles of the signal for counting (the IWDTCR.CKS[3:0] bits determine how many cycles of the signal from the IWDTCLK make up one cycle for counting). Therefore, writing FFh to the IWDTRR should be completed four cycles before the counter underflows. The value of the counter is checked by the counter bits (IWDTSR.CNTVAL[13:0]).

Figure 21.4 shows refresh-operation waveforms for the count clock of the IWDTCLK.

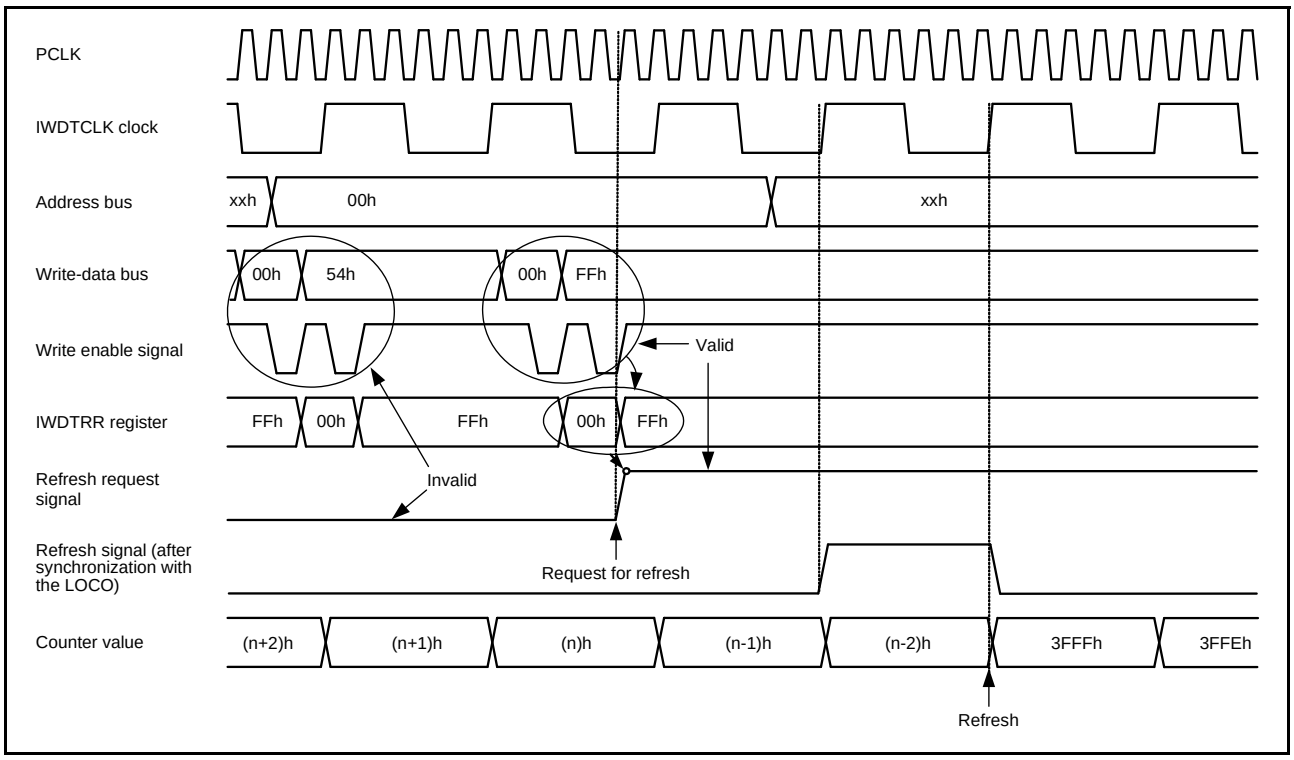


Figure 21.4 Refresh Operation Waveform (IWDTCR.CKS[3:0] = 0000b, IWDTCR.TOPS[1:0] = 11b)

21.3.4 Status Flags

Reset requests from the refresh-error flag (IWDTSR.REFEF) and underflow flag (IWDTSR.UNDFF) are retained after output of the reset signal from the IWDT.

Thus, after release from the reset state, read the IWDTSR.REFEF and UNDFF bits to check for these reset requests.

For both flags, writing "0" clears the bit and writing "1" has no effect.

Leaving the status flags set does not affect operation. If the flags are not cleared, at the time of the next reset from the IWDT, the earlier reset request is cleared and the new reset request is written.

21.4 Usage Notes

21.4.1 Limitation on Transitions to Low-Power-Consumption Modes

Writing to the IWDTCR or refresh operations brings the IWDT into use. When the IWDT is in use, even executing a WAIT instruction while the SSBY bit in the SBYCR is set to 1 will not cause a transition to software standby mode; instead, the transition will be to sleep mode or all-module-clock-stop mode. Furthermore, the reset source for the IWDT triggers release from the given mode, while the other reset sources do not. For details, see section 6., Resets.

22. Serial Communications Interface (SCIb)

The RX62T Group has three independent serial communications interface (SCI) units.
The SCI can handle both asynchronous and clock synchronous serial communications.
Asynchronous serial data communications can be carried out with standard asynchronous communications chips such as a Universal Asynchronous Receiver/Transmitter (UART) or Asynchronous Communications Interface Adapter (ACIA).
The SCI also supports the smart card (IC card) interface (SMCI) conforming to ISO/IEC 7816-3 (standards for Identification Cards) as an extended asynchronous communications mode.

22.1 Overview

Table 22.1 lists the specifications of the SCI.
Figure 22.1 shows a block diagram of the SCI0 to SCI2.

Table 22.1 Specifications of SCI

Item		Specifications
Serial communications mode		• Asynchronous • Clock synchronous • Smart card interface
Transfer speed		Bit rate specifiable with on-chip baud rate generator.
Full-duplex communications		Transmitter: Enables continuous transmission by double-buffering. Receiver: Enables continuous reception by double-buffering.
Input/output pins		See Table 22.2.
Data transfer		Selectable from LSB-first or MSB-first transfer
Interrupt sources		Transmit-end, transmit-data-empty, receive-data-full, and receive error
Power consumption reduction function		Module stop state can be set for each unit.
Asynchronous mode	Data length	7 or 8 bits
	Transmission stop bit	1 or 2 bits
	Parity	Even, odd, or none
	Receive error detection	Parity, overrun, and framing errors
	Break detection	Break can be detected by reading RXDn (n = 0 to 2) pin level directly in case of a framing error
	Clock source	Selectable from internal or external clock
	Multi-processor communications function	Serial communication among multiple processors
	Noise cancellation	Capable of canceling noise on the RXDn (n = 0 to 2) pin.
Clock synchronous mode	Data length	8 bits
	Receive error detection	Overrun errors
Smart card interface mode	Error processing	An error signal can be automatically transmitted on detection of a parity error during reception
		Data can be automatically re-transmitted on receiving an error signal during transmission
	Data type	Both direct convention and inverse convention are supported.

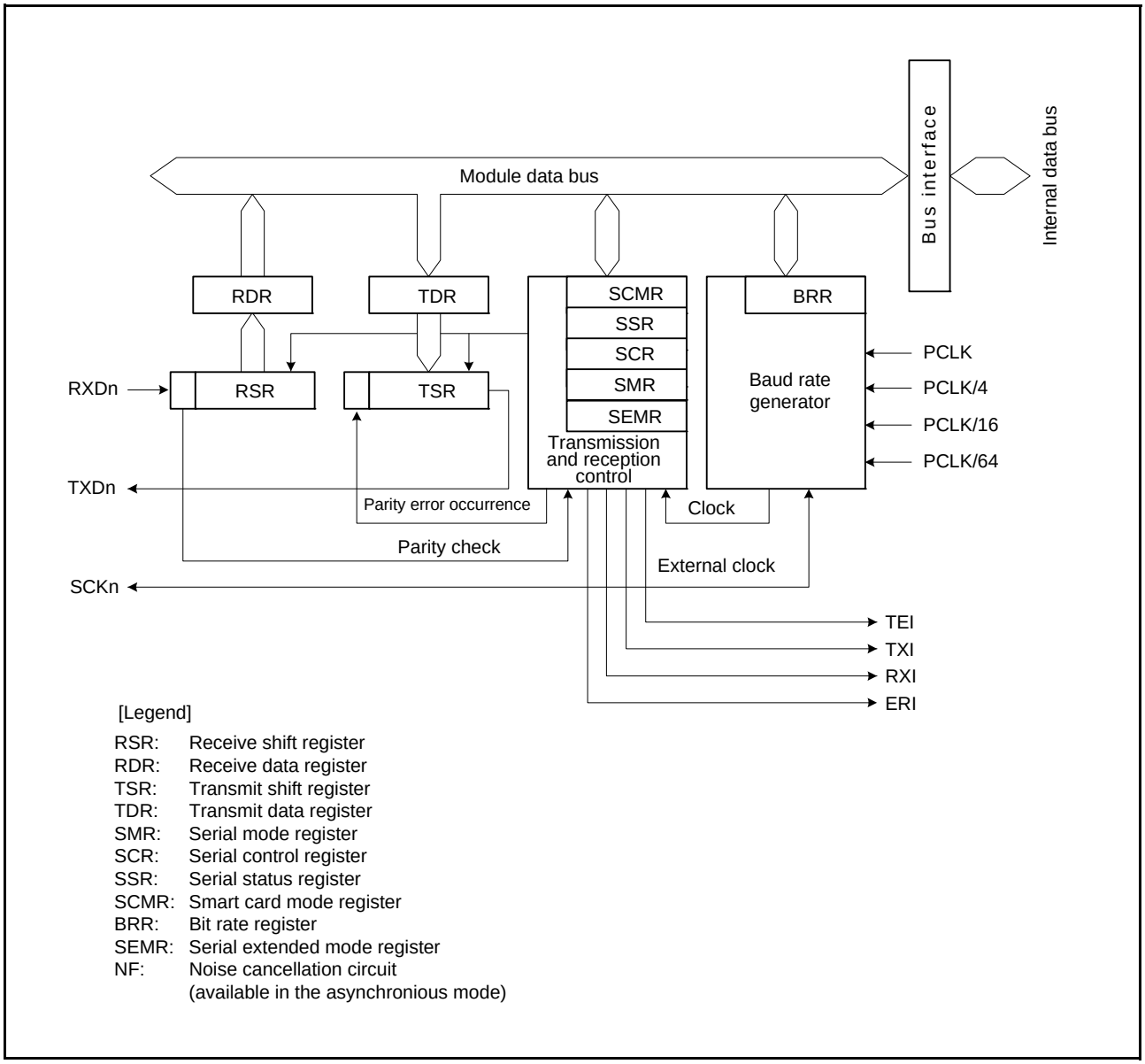


Figure 22.1 Block Diagram of SCI0 to SCI2

Table 22.2 lists the pin configuration of the SCI/SMCI.

Table 22.2 Pin Configuration of SCI

Channel	Pin Name	I/O	Function
SCI0/SMCI0	SCK0	I/O	SCI0/SMCI0 clock input/output
	RXD0	Input	SCI0/SMCI0 receive data input
	TXD0	Output	SCI0/SMCI0 transmit data output
SCI1/SMCI1	SCK1	I/O	SCI1/SMCI1 clock input/output
	RXD1	Input	SCI1/SMCI1 receive data input
	TXD1	Output	SCI1/SMCI1 transmit data output
SCI2/SMCI2	SCK2	I/O	SCI2/SMCI2 clock input/output
	RXD2	Input	SCI2/SMCI2 receive data input
	TXD2	Output	SCI2/SMCI2 transmit data output

22.2 Serial Communications Interface Mode

22.2.1 Register Descriptions

Table 22.3 lists the registers of the SCI.

Table 22.3 Registers of SCI

Channel	Register Name	Symbol	Value after Reset	Address	Access Size
SCI0	Serial mode register	SMR	00h	0008 8240h	8
	Bit rate register	BRR	FFh	0008 8241h	8
	Serial control register	SCR	00h	0008 8242h	8
	Transmit data register	TDR	FFh	0008 8243h	8
	Serial status register	SSR	84h	0008 8244h	8
	Receive data register	RDR	00h	0008 8245h	8
	Smart card mode register	SCMR	F2h	0008 8246h	8
	Serial extended mode register	SEMR	00h	0008 8247h	8
SCI1	Serial mode register	SMR	00h	0008 8248h	8
	Bit rate register	BRR	FFh	0008 8249h	8
	Serial control register	SCR	00h	0008 824Ah	8
	Transmit data register	TDR	FFh	0008 824Bh	8
	Serial status register	SSR	84h	0008 824Ch	8
	Receive data register	RDR	00h	0008 824Dh	8
	Smart card mode register	SCMR	F2h	0008 824Eh	8
	Serial extended mode register	SEMR	00h	0008 824Fh	8
SCI2	Serial mode register	SMR	00h	0008 8250h	8
	Bit rate register	BRR	FFh	0008 8251h	8
	Serial control register	SCR	00h	0008 8252h	8
	Transmit data register	TDR	FFh	0008 8253h	8
	Serial status register	SSR	84h	0008 8254h	8
	Receive data register	RDR	00h	0008 8255h	8
	Smart card mode register	SCMR	F2h	0008 8256h	8
	Serial extended mode register	SEMR	00h	0008 8257h	8

22.2.1.1 Receive Shift Register (RSR)

RSR is a shift register which is used to receive serial data input from the RXDn pin and converts it into parallel data. When one frame of data has been received, it is transferred to RDR automatically.
RSR cannot be directly accessed by the CPU.

22.2.1.2 Receive Data Register (RDR)

Address: SCI0.RDR 0008 8245h, SCI1.RDR 0008 824Dh, SCI2.RDR 0008 8255h

	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	0	0	0	0	0	0	0	0

RDR is an 8-bit register that stores receive data.
When the SCI has received one frame of serial data, it transfers the received serial data from RSR to RDR where it is stored. This allows RSR to receive the next data.
Since RSR and RDR function as a double buffer in this way, continuous receive operations can be performed.
Read RDR only once after a receive data full interrupt (RXI) has occurred. Note that if next one frame of data is received before reading receive data from RDR, an overrun error occurs.
RDR cannot be written to by the CPU.

22.2.1.3 Transmit Data Register (TDR)

Address: SCI0.TDR 0008 8243h, SCI1.TDR 0008 824Bh, SCI2.TDR 0008 8253h

	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	1	1	1	1	1	1	1	1

TDR is an 8-bit register that stores transmit data.
When the SCI detects that TSR is empty, it transfers the transmit data written in TDR to TSR and starts transmission.
The double-buffered structures of TDR and TSR enable continuous serial transmission. If the next transmit data has already been written to TDR when one frame of data is transmitted, the SCI transfers the written data to TSR to continue transmission.
The CPU is able to read from or write to TDR at any time. Only write data for transmission to TDR once after each instance of the transmit data empty interrupt (TXI).

22.2.1.4 Transmit Shift Register (TSR)

TSR is a shift register that transmits serial data.
To perform serial data transmission, the SCI first automatically transfers transmit data from TDR to TSR, and then sends the data to the TXDn pin.
TSR cannot be directly accessed by the CPU.

22.2.1.5 Serial Mode Register (SMR)

Address: SCI0.SMR 0008 8240h, SCI1.SMR 0008 8248h, SCI2.SMR 0008 8250h

	b7	b6	b5	b4	b3	b2	b1	b0
	CM	CHR	PE	PM	STOP	MP	CKS[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Function	R/W
b1, b0	CKS[1:0]	Clock Select	b1 b0 00: PCLK clock (n = 0)*1 01: PCLK/4 clock (n = 1)*1 10: PCLK/16 clock (n = 2)*1 11: PCLK/64 clock (n = 3)*1	R/W*4
b2	MP	Multi-Processor Mode	(Valid only in asynchronous mode) 0: Multi-processor communications function is disabled 1: Multi-processor communications function is enabled	R/W*4
b3	STOP	Stop Bit Length	(Valid only in asynchronous mode) 0: 1 stop bit 1: 2 stop bits	R/W*4
b4	PM	Parity Mode	(Valid only when the PE bit is 1 in asynchronous mode) 0: Selects even parity 1: Selects odd parity	R/W*4
b5	PE	Parity Enable	(Valid only in asynchronous mode) When transmitting 0: Parity bit addition is not performed 1: The parity bit is added When receiving 0: Parity bit checking is not performed 1: The parity bit is checked	R/W*4
b6	CHR	Character Length	(Valid only in asynchronous mode) 0: Selects 8 bits as the data length*2 1: Selects 7 bits as the data length*3	R/W*4
b7	CM	Communications Mode	0: Asynchronous mode 1: Clock synchronous mode	R/W*4

Note 1. n is the decimal notation of the value of n in BRR (see section 22.2.1.9, Bit Rate Register (BRR).
Note 2. In clock synchronous mode, this bit setting is invalid and a fixed data length of 8 bits is used.
Note 3. LSB-first is fixed and the MSB (bit 7) in TDR is not transmitted in transmission.
Note 4. Writable only when TE in SCR = 0 and RE in SCR = 0 (both serial transmission and reception are disabled).

SMR is used to set the SCI's serial transfer format and select the clock source for the on-chip baud rate generator.

CKS[1:0] Bits (Clock Select)

These bits select the clock source for the on-chip baud rate generator.
For the relation between the settings of these bits and the baud rate, see section 22.2.1.9, Bit Rate Register (BRR).

MP Bit (Multi-Processor Mode)

Disables/enables the multi-processor communications function. The settings of the PE bit and PM bit are invalid in multi-processor mode.

STOP Bit (Stop Bit Length)

Selects the stop bit length in transmission.
In reception, only the first stop bit is checked regardless of this bit setting. If the second stop bit is 0, it is treated as the start bit of the next transmit frame.

PM Bit (Parity Mode)

Selects the parity mode (even or odd) for transmission and reception.
The setting of the PM bit is invalid in multi-processor mode.

PE Bit (Parity Enable)

When this bit is set to 1, the parity bit is added to transmit data, and the parity bit is checked in reception.
Irrespective of the setting of the PE bit, the parity bit is not added or checked in multi-processor format.

CHR Bit (Character Length)

Selects the data length for transmission and reception.
In clock synchronous mode, a fixed data length of 8 bits is used.

CM Bit (Communications Mode)

Selects asynchronous or clock synchronous mode.

22.2.1.6 Serial Control Register (SCR)

Address: SC 0.SCR 0008 8242h, SCI1.SCR 0008 824Ah, SCI2.SCR 0008 8252h

	b7	b6	b5	b4	b3	b2	b1	b0
	TIE	RIE	TE	RE	MPIE	TEIE	CKE[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Function	R/W
b1, b0	CKE[1:0]	Clock Enable	• For SCI0 to SCI2 Asynchronous mode b1 b0 0 0: On-chip baud rate generator The SCKn pin functions as I/O port. 0 1: On-chip baud rate generator The clock with the same frequency as the bit rate is output from the SCKn pin. 1 0: External clock Input a clock signal with a frequency 16 times the bite rate from the SCKn pin. Input a clock signal with a frequency eight times the bit rate when the SEMR.ABCS bit is 1. 1 1: External clock Input a clock signal with a frequency 16 times the bite rate from the SCKn pin. Input a clock signal with a frequency eight times the bit rate when the SEMR.ABCS bit is 1. Clock synchronous mode b1 b0 0 0: Internal clock The SCKn pin functions as the clock output pin. 0 1: Internal clock The SCKn pin functions as the clock output pin. 1 0: External clock The SCKn pin functions as the clock input pin. 1 1: External clock The SCKn pin functions as the clock input pin.	R/W*1
b2	TEIE	Transmit End Interrupt Enable	0: A TEI interrupt request is disabled 1: A TEI interrupt request is enabled	R/W
b3	MPIE	Multi-Processor Interrupt Enable	(Valid in asynchronous mode when SMR.MP = 1) 0: Normal reception 1: The multi-processor reception	R/W
b4	RE	Receive Enable	0: Serial reception is disabled 1: Serial reception is enabled	R/W*2
b5	TE	Transmit Enable	0: Serial transmission is disabled 1: Serial transmission is enabled	R/W*2
b6	RIE	Receive Interrupt Enable	0: RXI and ERI interrupt requests are disabled 1: RXI and ERI interrupt requests are enabled	R/W
b7	TIE	Transmit Interrupt Enable	0: A TXI interrupt request is disabled 1: A TXI interrupt request is enabled	R/W

Note 1. Writable only when TE = 0 and RE = 0.
Note 2. While the SMR.CM bit is 1, 1 can be written only when TE = 0 and RE = 0. After setting TE or RE to 1, only 0 can be written in TE and RE.
While the SMR.CM bit is 0, bits are writable by any timing.

SCR is a register that enables or disables the SCI transfer operations and selects the transfer clock source.

CKE[1:0] Bits (Clock Enable)

These bits select the clock source and SCKn pin function.

TEIE Bit (Transmit End Interrupt Enable)

Enables or disables a TEI interrupt request.
A TEI interrupt request is disabled by clearing the TEIE bit to 0.

MPIE Bit (Multi-Processor Interrupt Enable)

When the MPIE bit is set to 1, the receive data (SSR.MPB bit is 0) is not transferred from the RSR to the RDR, a receive error is not detected, and setting the flags ORER and FER to 1 is disabled.
When the receive data includes the MPB bit is set to 1, the SSR.MPB bit is set to 1, the MPIE bit is automatically cleared to 0 and normal operation is resumed. The RXI and ERI interrupt requests are enabled (if the RIE bit in SCR is set to 1), and setting the flags ORER and FER to 1 is enabled. For details, see section 22.2.3, Multi-Processor Communications Function.
MPIE should be set to 0 if multi-processor communications function is not to be used.

RE Bit (Receive Enable)

Enables or disables serial reception.
When this bit is set to 1, serial reception is started by detecting the start bit in asynchronous mode or the synchronous clock input in clock synchronous mode. Note that SMR should be set prior to setting the RE bit to 1 in order to designate the reception format.
Even if reception is halted by clearing the RE bit to 0, the ORER, FER, and PER flags in SSR are not affected and the previous value is retained.

TE Bit (Transmit Enable)

Enables or disables serial transmission.
When this bit is set to 1, serial transmission is started by writing transmit data to TDR. Note that SMR should be set prior to setting the TE bit to 1 in order to designate the transmission format.

RIE Bit (Receive Interrupt Enable)

Enables or disables RXI and ERI interrupt requests.
An RXI interrupt request is disabled by clearing the RIE bit to 0.
An ERI interrupt request can be cancelled by reading 1 from the ORER, FER, or PER flag in SSR and then clearing the flag to 0, or clearing the RIE bit to 0.

TIE Bit (Transmit Interrupt Enable)

Enables or disables notification of a TXI interrupt request.
Notification of a TXI interrupt request is disabled by clearing the TIE bit to 0.

22.2.1.7 Serial Status Register (SSR)

Address: SCI0.SSR 0008 8244h, SCI1.SSR 0008 824Ch, SCI2.SSR 0008 8254h

	b7	b6	b5	b4	b3	b2	b1	b0
	TDRE	RDRF	ORER	FER	PER	TEND	MPB	MPBT
Value after reset:	1	0	0	0	0	1	0	0

Bit	Symbol	Bit Name	Function	R/W
b0	MPBT	Multi-Processor Bit Transfer	Sets the multi-processor bit for adding to the transmission frame	R/W
b1	MPB	Multi-Processor	Value of the multi-processor bit in the reception frame	R
b2	TEND	Transmit End Flag	0: A character is being transmitted. 1: Character transfer has been completed.	R
b3	PER	Parity Error Flag	0: No parity error occurred 1: A parity error has occurred	R/(W)*1
b4	FER	Framing Error Flag	0: No framing error occurred 1: A framing error has occurred	R/(W)*1
b5	ORER	Overrun Error Flag	0: No overrun error occurred 1: An overrun error has occurred	R/(W)*1
b6	RDRF	Receive Data Full Flag	0: When data is transferred from RDR 1: When data has been received normally, and transferred from RSR to RDR	R/(W)*2
b7	TDRE	Transmit Data Empty Flag	0: When data is transferred to TDR 1: When data is transferred from TDR to TSR	R/(W)*2

Note 1. Only 0 can be written to this bit after reading it as 1, to clear the flag.
Note 2. Write 1 when writing is necessary.

SSR is a register containing status flags of the SCI and the transmission/reception multi-processor bit.

MPBT Bit (Multi-Processor Bit Transfer)

Sets the value of the multi-processor bit for adding to the transmission frame.

MPB Bit (Multi-Processor)

Holds the value of the multi-processor bit in the reception frame. This bit does not change when the RE bit in SCR is 0.

TEND Flag (Transmission End Flag)

Indicates completion of transmission.
[Setting conditions]

- Clearing of the SCR.TE bit to 0 (disabling serial transmission operations)
- The TDR is not updated at the time of transmission of the tail-end bit of a character being transmitted

[Clearing condition]

- Writing of further data for transmission to the TDR

When the TEND flag is cleared by writing the data for transmission to the TDR, read the TEND flag and check that it has actually been cleared to 0.

PER Bit (Parity Error Flag)

Indicates that a parity error has occurred during reception in asynchronous mode and the reception ends abnormally.
[Setting condition]

- When a parity error is detected during reception
  Although receive data when the parity error occurs is transferred to RDR, no RXI interrupt request occurs. Note that when the PER flag is being set to 1, the subsequent serial reception cannot be transferred to RDR.

[Clearing condition]

- When a 0 is written to PER after reading PER = 1 (after writing a 0 to it, read the PER bit to check that it has actually been cleared to 0.)
  Even when the RE bit in SCR is cleared to 0 (which indicates that serial reception is disabled), the PER flag is not affected and retains its previous value.

FER Bit (Framing Error Flag)

Indicates that a framing error has occurred during reception in asynchronous mode and the reception ends abnormally.
[Setting condition]

- When the stop bit is 0
  In 2-stop-bit mode, only the first stop bit is checked whether it is 1 but the second stop bit is not checked. Note that although receive data when the framing error occurs is transferred to RDR, no RXI interrupt request occurs. In addition, when the FER flag is being set to 1, the subsequent serial reception cannot be transferred to RDR.

[Clearing condition]

- When a 0 is written to FER after reading FER = 1 (After writing a 0 to it, read the FER bit to check that it has actually been cleared to 0.)
  Even when the RE bit in SCR is cleared to 0, the FER flag is not affected and retains its previous value.

ORER Bit (Overrun Error Flag)

Indicates that an overrun error has occurred during reception and the reception ends abnormally.
[Setting condition]

- When the next data is received before receive data is read from RDR
  In RDR, receive data prior to an overrun error occurrence is retained, but data received after the overrun error occurrence is lost. When the ORER flag is set to 1, subsequent serial reception cannot be performed. Note that, in clock synchronous mode, serial transmission also cannot continue.

[Clearing condition]

- When a 0 is written to ORER after reading ORER = 1 (After writing a 0 to it, read the ORER bit to check that it has actually been cleared to 0.)
  Even when the RE bit in SCR is cleared to 0, the ORER flag is not affected and retains its previous value.

RDRF Bit (Receive Data Full Flag)

Indicates whether RDR has received data.
[Setting condition]

- When data has been received normally, and transferred from RSR to RDR

[Clearing condition]

- When data is transferred from RDR

TDRE Bit (Transmit Data Empty Flag)

Indicates whether TDR has data to be transmitted.

[Setting condition]

- When data is transferred from TDR to TSR

[Clearing condition]

- When data is transferred to TDR

22.2.1.8 Smart Card Mode Register (SCMR)

Address: SCI0.SSR 0008 8244h, SCI1.SSR 0008 824Ch, SCI2.SSR 0008 8254h

	b7	b6	b5	b4	b3	b2	b1	b0
	BCP2	—	—	—	SDIR	SINV	—	SMIF
Value after reset:	1	1	1	1	0	0	1	0

Bit	Symbol	Bit Name	Function	R/W
b0	SMIF	Smart Card Interface Mode Select	0: Serial communications interface mode 1: Smart card interface mode	R/W*1
b1	—	Reserved	This bit is always read as 1. The write value should always be 1.	R/W
b2	SINV	Smart Card Data Invert	0: TDR contents are transmitted as they are. Receive data is stored as it is in RDR. 1: TDR contents are inverted before being transmitted. Receive data is stored in inverted form in RDR.	R/W*1
b3	SDIR	Bit Order Select	0: Transfer with LSB-first 1: Transfer with MSB-first	R/W*1
b6 to b4	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W
b7	BCP2	Base Clock Pulse 2	Selects the number of base clock cycles in combination with the BCP1 and BCP0 bits in SMR. Setting values in BCP2 bit in SCMR and BCP1 and BCP0 bits in SMR BCP2 BCP1 BCP0 0 0 0: 93 clock cycles (S = 93)*2 0 0 1: 128 clock cycles (S = 128)*2 0 1 0: 186 clock cycles (S = 186)*2 0 1 1: 512 clock cycles (S = 512)*2 1 0 0: 32 clock cycles (S = 32)*2 (Initial Value) 1 0 1: 64 clock cycles (S = 64)*2 1 1 0: 372 clock cycles (S = 372)*2 1 1 1: 256 clock cycles (S = 256)*2	R/W*1

Note 1. Writable only when TE in SCR = 0 and RE in SCR = 0 (both serial transmission and reception are disabled).
Note 2. S is the value of S in BRR (see section 22.2.1.9, Bit Rate Register (BRR).

SCMR selects smart card interface mode and its format.

SMIF Bit (Smart Card Interface Mode Select)

When this bit is set to 1, smart card interface mode is selected.

When this bit is set to 0, asynchronous or clock synchronous mode is selected.

SINV Bit (Smart Card Data Invert)

Inverts the transmit/receive data logic level. This bit does not affect the logic level of the parity bit. To invert the parity bit, invert the PM bit in SMR.

SDIR Bit (Bit Order Select)
Selects the serial/parallel conversion format.

BCP2 Bit (Base Clock Pulse 2)

Selects the number of base clock cycles in a 1-bit data transfer time in smart card interface mode. Set this bit in combination with the BCP1 and BCP0 bits in SMR.

22.2.1.9 Bit Rate Register (BRR)

Address: SC 0.BRR 0008 8241h, SCI1.BRR 0008 8249h, SCI2.BRR 0008 8251h

	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	1	1	1	1	1	1	1	1

BRR is an 8-bit register that adjusts the bit rate.
As the SCI performs baud rate generator control independently for each channel, different bit rates can be set for each channel. Table 22.4 shows the relationships between the N setting in BRR and bit rate B for normal asynchronous mode and clock synchronous mode, and smart card interface mode.
The initial value of BRR is FFh.
BRR can be read from by the CPU at all times, but it can be written to only when the TE and RE bits in SCR are 0. Table 22.5 shows sample N settings in BRR in normal asynchronous mode. Table 22.6 shows the maximum bit rate settable for each operating frequency. Table 22.8 and Table 22.10 show sample N settings in BRR in clock synchronous mode and smart card interface mode, respectively. In smart card interface mode, the number of base clock cycles S in a 1-bit data transfer time can be selected. For details, see section 22.3.3.2, Receive Data Sampling Timing and Reception Margin. Table 22.7 and Table 22.9 show the maximum bit rates with external clock input. When the asynchronous mode base clock select bit (ABCS) in the serial extended mode register (SEMR) is set to 1 in asynchronous mode, the bit rate is two times that of shown in Table 22.5.

Table 22.4 Relationships between N Setting in BRR and Bit Rate B

Mode	ABCS Bit in SEMR	BRR Setting	Error
Asynchronous	0	$N = \frac{PCLK \times 10^6}{64 \times 2^{2n-1} \times B} - 1$	$Error\ (\%) = \{ \frac{PCLK \times 10^6}{B \times 64 \times 2^{2n-1} \times (N+1)} - 1 \} \times 100$
	1	$N = \frac{PCLK \times 10^6}{32 \times 2^{2n-1} \times B} - 1$	$Error\ (\%) = \{ \frac{PCLK \times 10^6}{B \times 32 \times 2^{2n-1} \times (N+1)} - 1 \} \times 100$
Clock synchronous		$N = \frac{PCLK \times 10^6}{8 \times 2^{2n-1} \times B} - 1$	

B: Bit rate (bps)
N: BRR setting for baud rate generator ($0 \leq N \leq 255$)
PCLK: Operating frequency (MHz)
n and S: Determined by the SMR setting shown in the following table.

SMR Setting		
CKS[1:0] Bits	**Clock Source**	**n**
0 0	PCLK clock	0
0 1	PCLK/4 clock	1
1 0	PCLK/16 clock	2
1 1	PCLK/64 clock	3

SCMR Setting	SMR Setting		
BCP2 Bit	**BCP[1:0] Bits**	**Base Clock**	**S**
0	0 0	93 clock cycles	93
0	0 1	128 clock cycles	128
0	1 0	186 clock cycles	186
0	1 1	512 clock cycles	512
1	0 0	32 clock cycles	32
1	0 1	64 clock cycles	64
1	1 0	372 clock cycles	372
1	1 1	256 clock cycles	256

Table 22.5 Examples of BRR Settings for Various Bit Rates (Asynchronous Mode) (1)

Bit Rate (bps)	Operating Frequency PCLK (MHz)											
	8			9.8304			10			12		
	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
110	2	141	0.03	2	174	-0.26	2	177	-0.25	2	212	0.03
150	2	103	0.16	2	127	0.00	2	129	0.16	2	155	0.16
300	1	207	0.16	1	255	0.00	2	64	0.16	2	77	0.16
600	1	103	0.16	1	127	0.00	1	129	0.16	1	155	0.16
1200	0	207	0.16	0	255	0.00	1	64	0.16	1	77	0.16
2400	0	103	0.16	0	127	0.00	0	129	0.16	0	155	0.16
4800	0	51	0.16	0	63	0.00	0	64	0.16	0	77	0.16
9600	0	25	0.16	0	31	0.00	0	32	-1.36	0	38	0.16
19200	0	12	0.16	0	15	0.00	0	15	1.73	0	19	-2.34
31250	0	7	0.00	0	9	-1.70	0	9	0.00	0	11	0.00
38400	—	—	—	0	7	0.00	0	7	1.73	0	9	-2.34

Bit Rate (bps)	Operating Frequency PCLK (MHz)								
	12.288			14			16		
	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
110	2	217	0.08	2	248	-0.17	3	70	0.03
150	2	159	0.00	2	181	0.16	2	207	0.16
300	2	79	0.00	2	90	0.16	2	103	0.16
600	1	159	0.00	1	181	0.16	1	207	0.16
1200	1	79	0.00	1	90	0.16	1	103	0.16
2400	0	159	0.00	0	181	0.16	0	207	0.16
4800	0	79	0.00	0	90	0.16	0	103	0.16
9600	0	39	0.00	0	45	-0.93	0	51	0.16
19200	0	19	0.00	0	22	-0.93	0	25	0.16
31250	0	11	2.40	0	13	0.00	0	15	0.00
38400	0	9	0.00	—	——	—	0	12	0.16

Note: • Notes:This is an example when the ABCS bit in SEMR is 0.
When the ABCS bit is set to 1, the bit rate is two times.

Table 22.5 Examples of BRR Settings for Various Bit Rates (Asynchronous Mode) (2)

Bit Rate (bps)	Operating Frequency PCLK (MHz)											
	17.2032			18			19.6608			20		
	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
110	3	75	0.48	3	79	-0.12	3	86	0.31	3	88	-0.25
150	2	223	0.00	2	233	0.16	2	255	0.00	3	64	0.16
300	2	111	0.00	2	116	0.16	2	127	0.00	2	129	0.16
600	1	223	0.00	1	233	0.16	1	255	0.00	2	64	0.16
1200	1	111	0.00	1	116	0.16	1	127	0.00	1	129	0.16
2400	0	223	0.00	0	233	0.16	0	255	0.00	1	64	0.16
4800	0	111	0.00	0	116	0.16	0	127	0.00	0	129	0.16
9600	0	55	0.00	0	58	-0.69	0	63	0.00	0	64	0.16
19200	0	27	0.00	0	28	1.02	0	31	0.00	0	32	-1.36
31250	0	16	1.20	0	17	0.00	0	19	-1.70	0	19	0.00
38400	0	13	0.00	0	14	-2.34	0	15	0.00	0	15	1.73

Bit Rate (bps)	Operating Frequency PCLK (MHz)											
	25			30			33			50		
	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
110	3	110	-0.02	3	132	0.13	3	145	0.33	3	221	-0.02
150	3	80	0.47	3	97	-0.35	3	106	0.39	3	162	-0.15
300	2	162	-0.15	2	194	0.16	2	214	-0.07	3	80	0.47
600	2	80	0.47	2	97	-0.35	2	106	0.39	2	162	-0.15
1200	1	162	-0.15	1	194	0.16	1	214	-0.07	2	80	0.47
2400	1	80	0.47	1	97	-0.35	1	106	0.39	1	162	-0.15
4800	0	162	-0.15	0	194	0.16	0	214	-0.07	1	80	0.47
9600	0	80	0.47	0	97	-0.35	0	106	0.39	1	40	-0.77
19200	0	40	-0.76	0	48	-0.35	0	53	-0.54	0	80	0.47
31250	0	24	0.00	0	29	0	0	32	0	0	49	0.00
38400	0	19	1.73	0	23	1.73	0	26	-0.54	0	40	-0.77

Note: • This is an example when the ABCS bit in SEMR is 0.
When the ABCS bit is set to 1, the bit rate is two times.

Table 22.6 Maximum Bit Rate for Each Operating Frequency (Asynchronous Mode)

PCLK (MHz)	Maximum Bit Rate (bps)	n	N	PCLK (MHz)	Maximum Bit Rate (bps)	n	N
8	250000	0	0	18	562500	0	0
9.8304	307200	0	0	19.6608	614400	0	0
10	312500	0	0	20	625000	0	0
12	375000	0	0	25	781250	0	0
12.288	384000	0	0	30	937500	0	0
14	437500	0	0	33	1031250	0	0
16	500000	0	0	50	1562500	0	0
17.2032	537600	0	0				

Note: • When the ABCS bit in SEMR is set to 1, the bit rate is two times.

Table 22.7 Maximum Bit Rate with External Clock Input (Asynchronous Mode) (1)

PCLK (MHz)	External Input Clock (MHz)	Maximum Bit Rate (bps)	PCLK (MHz)	External Input Clock (MHz)	Maximum Bit Rate (bps)
8	2.0000	125000	18	4.5000	281250
9.8304	2.4576	153600	19.6608	4.9152	307200
10	2.5000	156250	20	5.0000	312500
12	3.0000	187500	25	6.2500	390625
12.288	3.0720	192000	30	7.5000	468750
14	3.5000	218750	33	8.2500	515625
16	4.0000	250000	50	12.500	781250
17.2032	4.3008	268800			

Note: • This is an example when the ABCS bit in SEMR is 0.

Table 22.7 Maximum Bit Rate with External Clock Input (Asynchronous Mode) (2)

PCLK (MHz)	External Input Clock (MHz)	Maximum Bit Rate (bps)	PCLK (MHz)	External Input Clock (MHz)	Maximum Bit Rate (bps)
8	2.0000	250000	18	4.5000	562500
9.8304	2.4576	307200	19.6608	4.9152	614400
10	2.5000	312500	20	5.0000	625000
12	3.0000	375000	25	6.2500	781250
12.288	3.0720	384000	30	7.5000	937500
14	3.5000	437500	33	8.2500	1031250
16	4.0000	500000	50	12.500	1562500
17.2032	4.3008	537600			

Note: • This is an example when the ABCS bit in SEMR is 1.

Table 22.8 BRR Settings for Various Bit Rates (Clock Synchronous Mode)

Bit Rate (bps)	Operating Frequency PCLK (MHz)															
	8		10		16		20		25		30		33		50	
	n	N	n	N	n	N	n	N	n	N	n	N	n	N	n	N
110																
250	3	124	—	—	3	249										
500	2	249	—	—	3	124	—	—			3	233				
1k	2	124	—	—	2	249	—	—	3	97	3	116	3	128	3	194
2.5k	1	199	1	249	2	99	2	124	2	155	2	187	2	205	3	77
5k	1	99	1	124	1	199	1	249	2	77	2	93	2	102	2	155
10k	0	199	0	249	1	99	1	124	1	155	1	187	1	205	2	77
25k	0	79	0	99	0	159	0	199	0	249	1	74	1	82	1	124
50k	0	39	0	49	0	79	0	99	0	124	0	149	0	164	1	61
100k	0	19	0	24	0	39	0	49	0	62	0	74	0	82	0	124
250k	0	7	0	9	0	15	0	19	0	24	0	29	0	32	0	49
500k	0	3	0	4	0	7	0	9	—	—	0	14	—	—	0	24
1M	0	1			0	3	0	4	—	—	—	—	—	—	—	—
2.5M			0	0*1			0	1	—	—	0	2	—	—	0	4
5M							0	0*1	—	—	—	—	—	—	—	—

Space: Setting prohibited.
—: Can be set, but the actual bit rate doesn't match the bit rate value in the table.
Note 1. Continuous transmission or reception is not possible.

Table 22.9 Maximum Bit Rate with External Clock Input (Clock Synchronous Mode)

PCLK (MHz)	External Input Clock (MHz)	Maximum Bit Rate (bps)	PCLK (MHz)	External Input Clock (MHz)	Maximum Bit Rate (bps)
8	1.3333	1333333.3	20	3.3333	3333333.3
10	1.6667	1666666.7	25	4.1667	4166666.7
12	2.0000	2000000.0	30	5.0000	5000000.0
14	2.3333	2333333.3	33	5.5000	5500000.0
16	2.6667	2666666.7	50	8.3333	8333333.3
18	3.0000	3000000.0			

Table 22.10 BRR Settings for Various Bit Rates (Smart Card Interface Mode, n = 0, S = 372)

Bit Rate (bps)	Operating Frequency PCLK (MHz)											
	7.1424			10.00			10.7136			13.00		
	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
9600	0	0	0.00	0	1	30	0	1	25	0	1	8.99

Bit Rate (bps)	Operating Frequency PCLK (MHz)											
	14.2848			16.00			18.00			20.00		
	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
9600	0	1	0.00	0	1	12.01	0	2	15.99	0	2	6.66

Bit Rate (bps)	Operating Frequency PCLK (MHz)											
	25.00			30.00			33.00			50.00		
	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
9600	0	3	12.49	0	3	5.01	0	4	7.59	0	6	0.01

Table 22.11 Maximum Bit Rate for Each Operating Frequency (Smart Card Interface Mode, S = 372)

PCLK (MHz)	Maximum Bit Rate (bps)	n	N	PCLK (MHz)	Maximum Bit Rate (bps)	n	N
10.00	13441	0	0	20.00	26882	0	0
10.7136	14400	0	0	25.00	33602	0	0
13.00	17473	0	0	30.00	40323	0	0
16.00	21505	0	0	33.00	44355	0	0
18.00	24194	0	0	50.00	67205	0	0

22.2.1.10 Serial Extended Mode Register (SEMR)

Address: SCI0.SEMR 0008 8247h, SCI1.SEMR 0008 824Fh, SCI2.SEMR 0008 8257h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	NFEN	ABCS	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Function	R/W
b3 to b0	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b4	ABCS	Asynchronous Mode Base Clock Select	(Valid only in asynchronous mode) 0: Selects 16 base clock cycles for 1-bit period 1: Selects 8 base clock cycles for 1-bit period	R/W*1
b5	NFEN	Noise Cancelling Function Select	(Valid only in asynchronous mode) 0: Disables noise cancellation for the RXDn pin 1: Enables noise cancellation for the RXDn pin	R/W*1
b7 to b6	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

Note 1. Writable only when TE in SCR = 0 and RE in SCR = 0 (both serial transmission and reception are disabled).

Settings in the SEMR select the number of clock cycles for 1 bit period and whether to enable or disable cancellation of noise on the RXDn pin in asynchronous mode.

ABCS Bit (Asynchronous Mode Base Clock Select)

Selects the number of base clock pulses for 1-bit period.

NFEN Bit (Noise Cancelling Function Select)

Selects whether to enable or disable noise cancellation. When the setting is “enabled”, noise cancellation is applied to signals on the reception pin (RXDn input). See section 22.4, Noise Cancellation.

22.2.2 Operation in Asynchronous Mode

Figure 22.2 shows the general format for asynchronous serial communications.
One frame consists of a start bit (Low), transmit/receive data, a parity bit, and stop bits (High).
In asynchronous serial communications, the communications line is usually held in the mark state (High).
The SCI monitors the communications line, and when it goes to the space state (Low), recognizes a start bit and starts serial communications.
Inside the SCI, the transmitter and receiver are independent units, enabling full-duplex communications. Both the transmitter and the receiver also have a double-buffered structure, so that data can be read or written during transmission or reception, enabling continuous data transmission and reception.

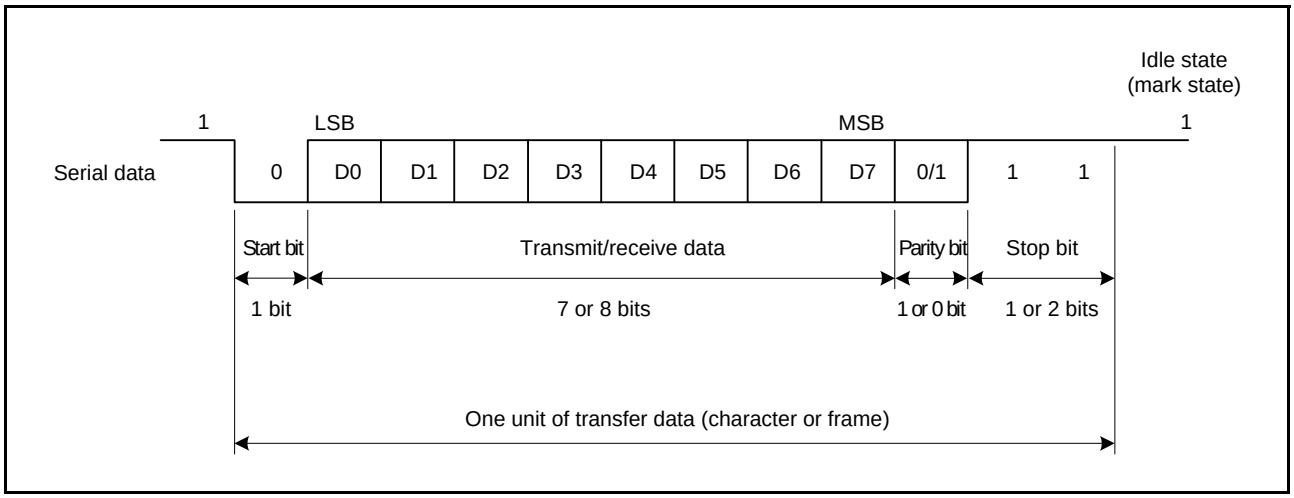


Figure 22.2 Format in Asynchronous Serial Communications (Example with 8-Bit Data, Parity, Two Stop Bits)

22.2.2.1 Serial Data Transfer Format

Table 22.12 shows the serial data transfer formats that can be used in asynchronous mode.
Any of 12 transfer formats can be selected according to the SMR setting. For details of multi-processor function, see section 22.2.3, Multi-Processor Communications Function.

Table 22.12 Serial Transfer Formats (Asynchronous Mode)

SMR Setting				Serial Transfer Format and Frame Length
CHR	PE	MP	STOP	1 2 3 4 5 6 7 8 9 10 11 12
0	0	0	0	S 8-bit data STOP
0	0	0	1	S 8-bit data STOP STOP
0	1	0	0	S 8-bit data P STOP
0	1	0	1	S 8-bit data P STOP STOP
1	0	0	0	S 7-bit data STOP
1	0	0	1	S 7-bit data STOP STOP
1	1	0	0	S 7-bit data P STOP
1	1	0	1	S 7-bit data P STOP STOP
0	—	1	0	S 8-bit data MPB STOP
0	—	1	1	S 8-bit data MPB STOP STOP
1	—	1	0	S 7-bit data MPB STOP
1	—	1	1	S 7-bit data MPB STOP STOP

S: Start bit
STOP: Stop bit
P: Parity bit
MPB: Multi-processor bit

22.2.2.2 Receive Data Sampling Timing and Reception Margin in Asynchronous Mode

In asynchronous mode, the SCI operates on a base clock with a frequency of 16 times*1 the bit rate.
In reception, the SCI samples the falling edge of the start bit using the base clock, and performs internal synchronization. Since receive data is sampled at the rising edge of the 8th pulse* of the base clock, data is latched at the middle of each bit, as shown in Figure 22.3. Thus the reception margin in asynchronous mode is determined by formula (1) below.

$$M = \left| (0.5 - \frac{1}{2N}) - (L - 0.5) F - \frac{D - 0.5}{N} (1+F) \right| \times 100\ [\%] \quad \cdots \text{ Formula (1)}$$

M: Reception margin
N: Ratio of bit rate to clock (N = 16 when ABCS in SEMR = 0, N = 8 when ABCS in SEMR = 1)
D: Duty cycle of clock (D = 0.5 to 1.0)
L: Frame length (L = 9 to 12)
F: Absolute value of clock frequency deviation

Assuming values of F = 0 and D = 0.5 in formula (1), the reception margin is determined by the formula below.

M = {0.5 - 1/(2 x 16)} × 100 (%) = 46.875%

However, this is only the computed value, and a margin of 20% to 30% should be allowed in system design.

Note 1. This is an example when the ABCS bit in SEMR is 0. When the ABCS bit is 1, a frequency of 8 times the bit rate is used as a base clock and receive data is sampled at the rising edge of the 4th pulse of the base clock.

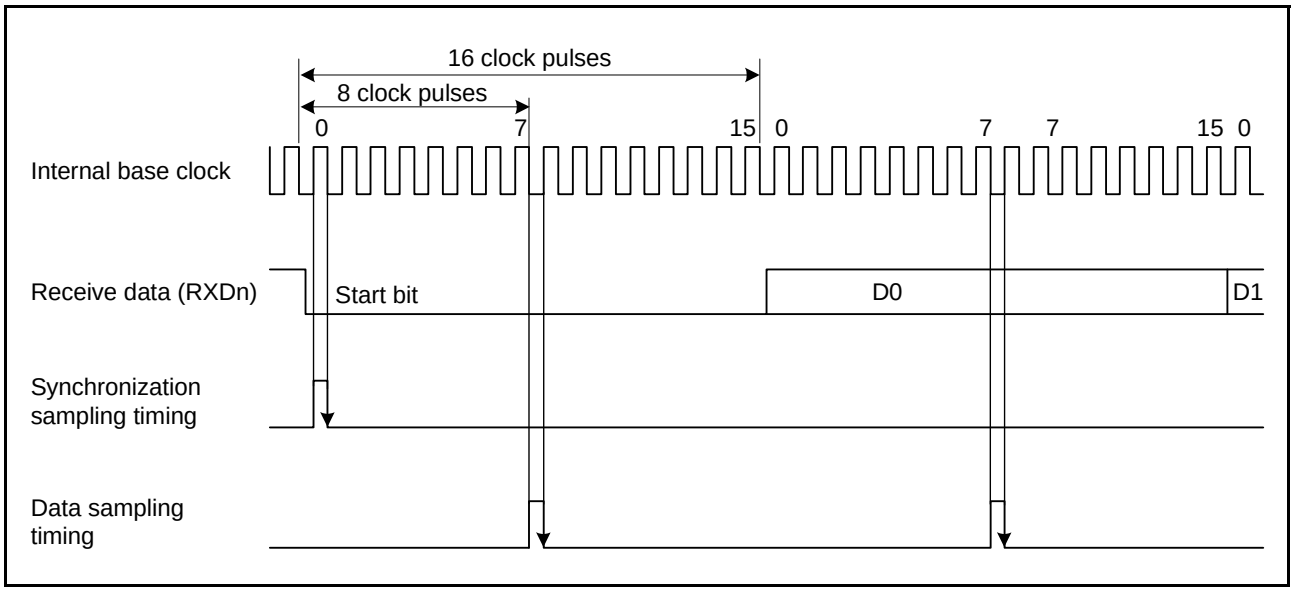


Figure 22.3 Receive Data Sampling Timing in Asynchronous Mode

22.2.2.3 Clock

Either an internal clock generated by the on-chip baud rate generator or an external clock input to the SCKn pin can be selected as the SCI's transfer clock, according to the setting of the CA bit in SMR and the CKE[1:0] bits in SCR.
When an external clock is input to the SCKn pin, the clock frequency should be 16 times the bit rate (when ABCS in SEMR = 0) and 8 times the bit rate (when ABCS in SEMR = 1).
When the SCI is operated on an internal clock, the clock can be output from the SCKn pin. The frequency of the clock output in this case is equal to the bit rate, and the phase is such that the rising edge of the clock is in the middle of the transmit data, as shown in Figure 22.4.

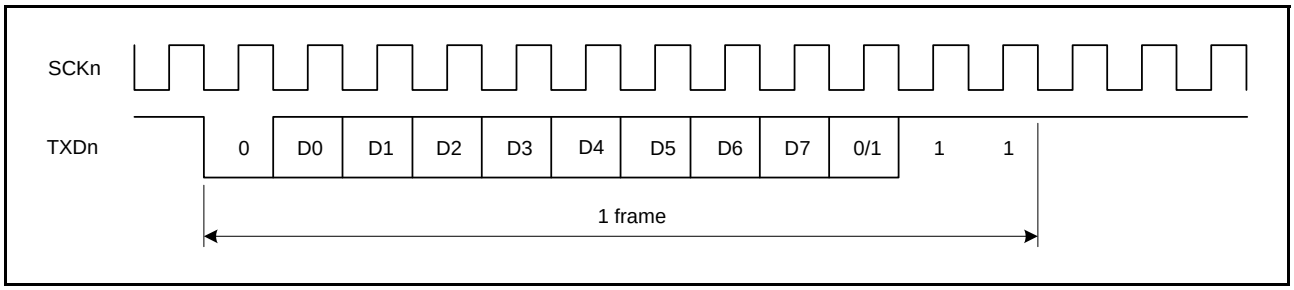


Figure 22.4 Phase Relationship between Output Clock and Transmit Data (Asynchronous Mode)

22.2.2.4 SCI Initialization (Asynchronous Mode)

Before transmitting and receiving data, start by writing the initial value "00h" to the SCR and then continue through the procedure for SCI given in the sample flowchart (Figure 22.5). Whenever the operating mode or transfer format is changed, the SCR must be initialized before the change is made.
When the external clock is used in asynchronous mode, ensure that the clock signal is supplied even during initialization.
Note that clearing the SCR.RE bit to 0 initializes neither the ORER, FER, and PER flags in SSR nor RDR.
Moreover, note that switching the value of the SCR.TE bit from 1 to 0 or 0 to 1 while the SCR.TIE bit is 1 leads to the generation of a TXI interrupt request.

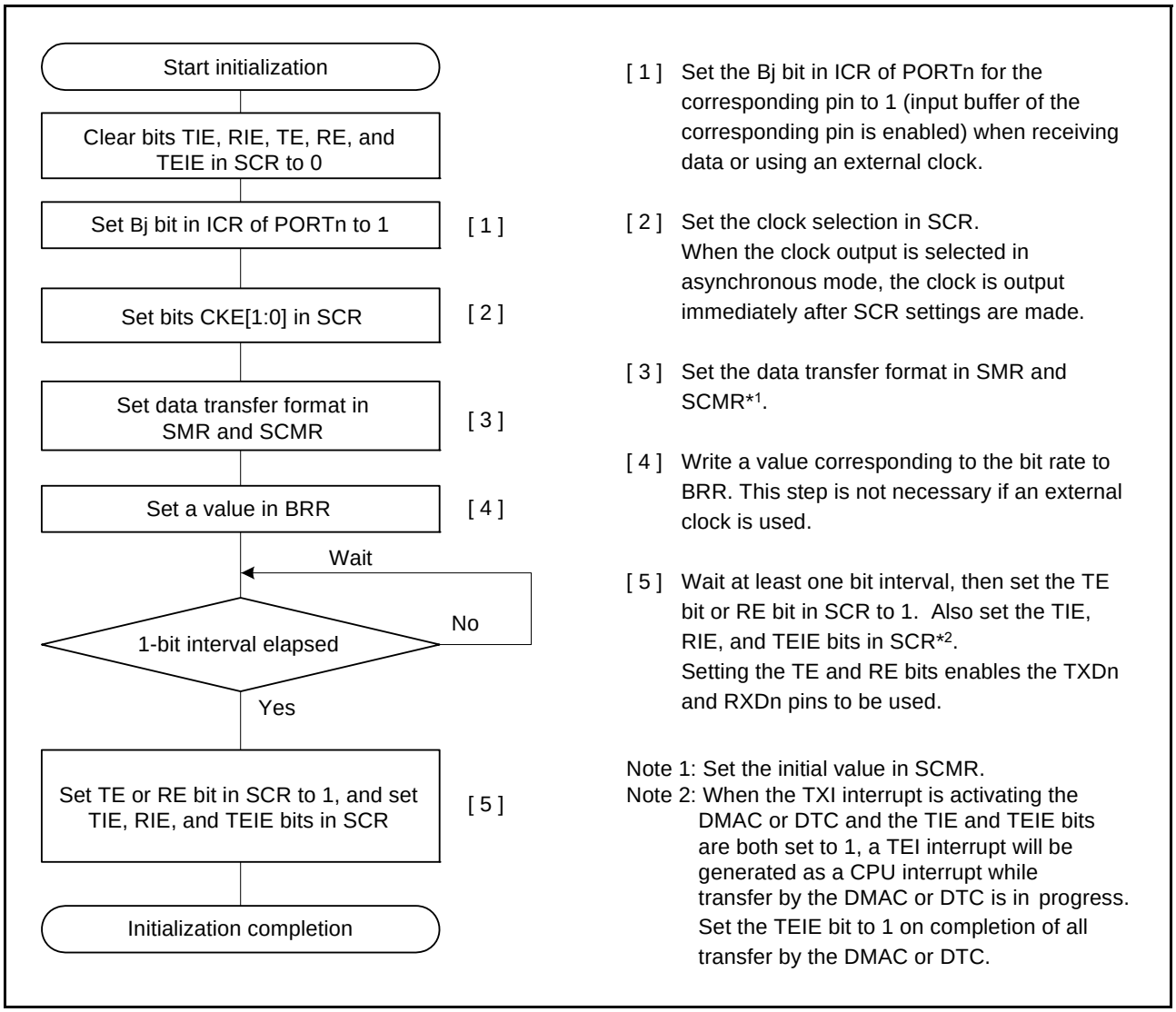


Figure 22.5 Sample SCI Initialization Flowchart (Asynchronous Mode)

22.2.2.5 Serial Data Transmission (Asynchronous Mode)

Figure 22.6 shows an example of the operation for serial transmission in asynchronous mode.
In serial transmission, the SCI operates as described below.

1. The SCI transfers data from TDR to TSR when data is written to TDR in the TXI interrupt processing routine. The TXI interrupt request at the beginning of transmission is generated when the TE bit in SCR is set to 1 after the TIE bit in SCR is set to 1 or when these two bits are set to 1 simultaneously by a single instruction.
2. After transferring data from TDR to TSR, the SCI starts transmission. If the TIE bit in SCR is 1 at this time, a TXI interrupt request is generated. Continuous transmission is enabled by writing the next transmit data to TDR in the TXI interrupt processing routine before transmission of the current transmit data is completed.
3. Data is sent from the TXDn pin in the following order: start bit, transmit data, parity bit or multi-processor bit (may be omitted depending on the format), and stop bit.
4. The SCI checks for updating of (writing to) TDR at the time of stop bit output.
5. When TDR is updated, the next transmit data is transferred from TDR to TSR, the stop bit is sent, and then serial transmission of the next frame is started.
6. If TDR is not updated, the TEND flag in SSR is set to 1, the stop bit is sent, and then the mark state is entered in which high is output. If the TEIE flag in SCR is 1 at this time, the TEND flag in SSR is set to 1 and a TEI interrupt request is generated.

Figure 22.7 shows a sample flowchart for serial transmission in asynchronous mode.

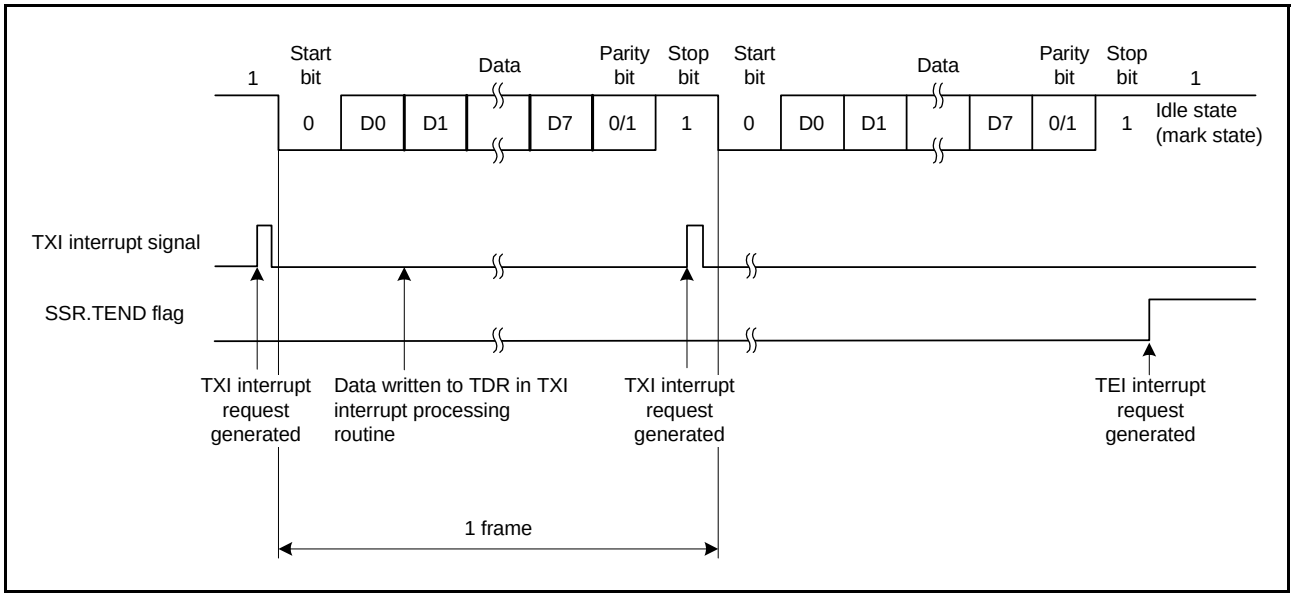
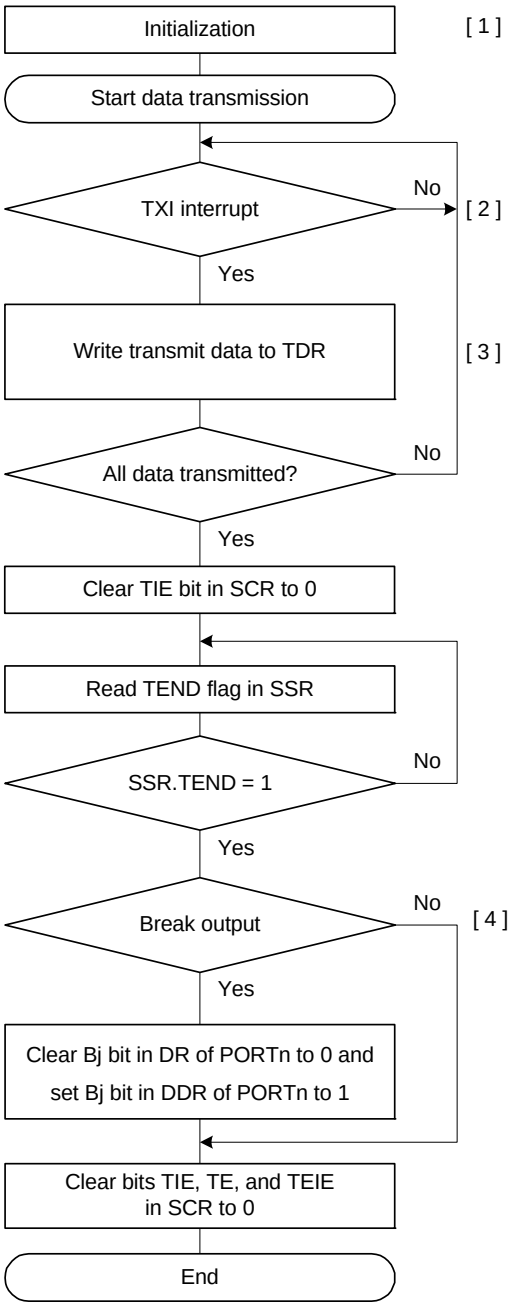


Figure 22.6 Example of Operation for Serial Transmission in Asynchronous Mode (Example with 8-Bit Data, Parity, One Stop Bit)



[1] SCIn initialization:
The TXDn pin is automatically designated as the transmit data output pin. After the TE bit in SCR is set to 1, the pin is driven high for a frame.

[2] Transmit data write to TDR by a TXI interrupt request:
When transmit data is transferred from TDR to TSR, a transmit data empty interrupt (TXI) request is generated. Write transmit data to TDR once in the TXI interrupt processing routine.

[3] Serial transmission continuation procedure:
To continue serial transmission, write transmit data to TDR once using a TXI interrupt request.
Transmit data can also be written to TDR by activating the DTC.

[4] Break output at the end of serial transmission:
To output a break in serial transmission, set the Bj bit in DDR of PORTn for the port corresponding to the TXDn pin to 1 (output port), clear the Bj bit in DR of PORTn to 0 (low level output), and then clear the TE bit in SCR to 0.

Figure 22.7 Example of Serial Transmission Flowchart in Asynchronous Mode

22.2.2.6 Serial Data Reception (Asynchronous Mode)

Figure 22.8 shows an example of the operation for serial data reception in asynchronous mode.
In serial data reception, the SCI operates as described below.

1.When the SCI monitors the communications line and detects a start bit, it performs internal synchronization, stores receive data in RSR, and checks the parity bit and stop bit.
2.If an overrun error occurs, the ORER flag in SSR is set to 1. If the RIE bit in SCR is 1 at this time, an ERI interrupt request is generated. Receive data is not transferred to RDR.
3.If a parity error is detected, the PER bit in SSR is set to 1 and receive data is transferred to RDR. If the RIE bit in SCR is 1 at this time, an ERI interrupt request is generated.
4.If a framing error (when the stop bit is 0) is detected, the FER bit in SSR is set to 1 and receive data is transferred to RDR. If the RIE bit in SCR is 1 at this time, an ERI interrupt request is generated.
5.When reception finishes successfully, receive data is transferred to RDR. If the RIE bit in SCR is 1 at this time, an RXI interrupt request is generated. Continuous reception is enabled by reading the receive data transferred to RDR in this RXI interrupt processing routine before reception of the next receive data is completed.

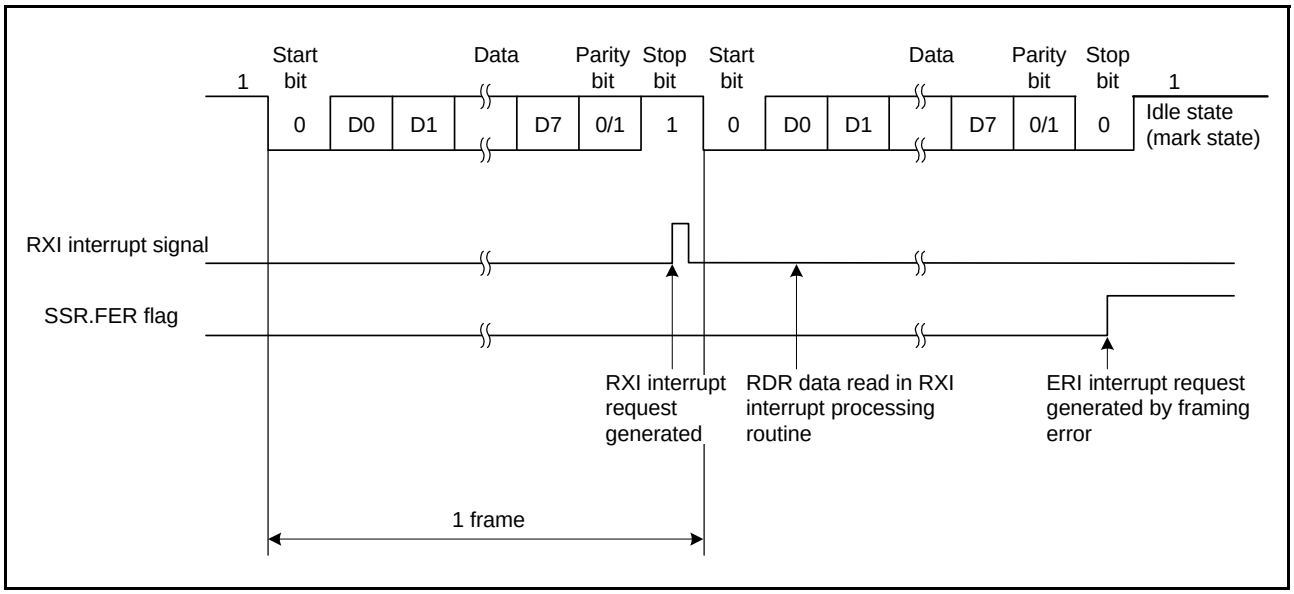
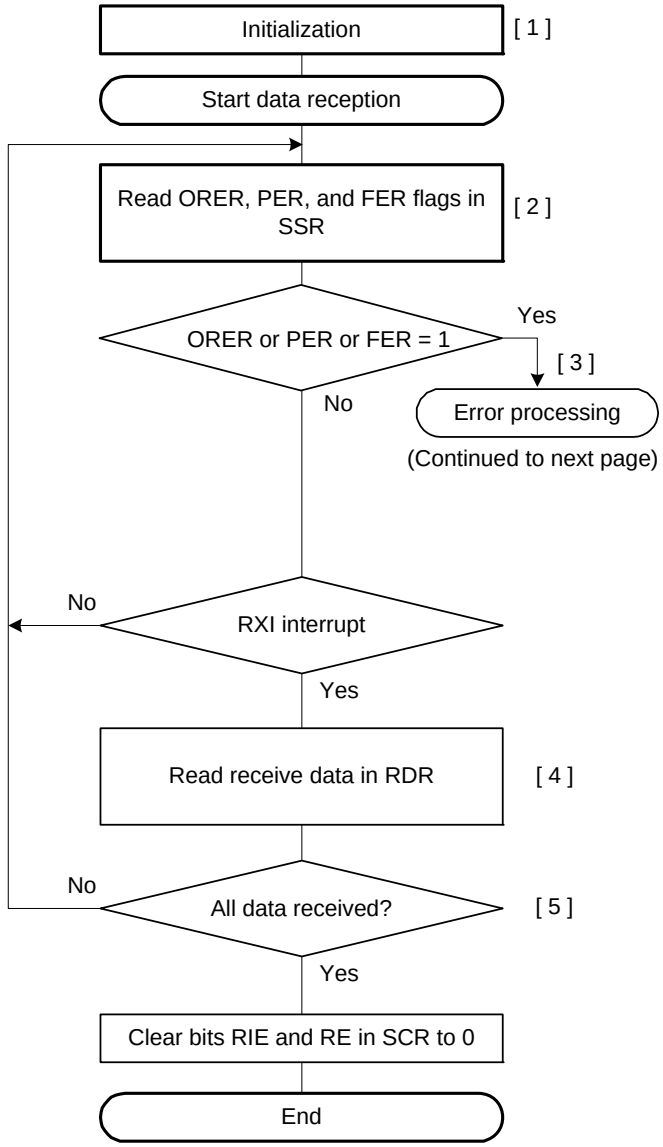


Figure 22.8 Example of SCI Operation for Serial Reception in Asynchronous Mode (Example with 8-Bit Data, Parity, One Stop Bit)

Table 22.13 shows the states of the SSR status flags and receive data handling when a receive error is detected.
If a receive error is detected, an ERI interrupt request is generated but an RXI interrupt request is not generated. Data reception cannot be resumed while the receive error flag is 1. Accordingly, clear the ORER, FER, and PER bits to 0 before resuming reception. Moreover, be sure to read the RDR during overrun error processing.
Figure 22.9 shows samples of flowcharts for serial data reception.

Table 22.13 SSR Status Flags and Receive Data Handling

SSR Status Flag				
ORER	**FER**	**PER**	**Receive Data**	**Receive Error Type**
1	0	0	Lost	Overrun error
0	1	0	Transferred to RDR	Framing error
0	0	1	Transferred to RDR	Parity error
1	1	0	Lost	Overrun error + framing error
1	0	1	Lost	Overrun error + parity error
0	1	1	Transferred to RDR	Framing error + parity error
1	1	1	Lost	Overrun error + framing error + parity error



[1] SCIn initialization:
The RXDn pin is automatically designated as the receive data input pin.

[2] [3] Receive error processing and break detection:
If a receive error occurs, an ERI interrupt is generated. An error is identified by reading the ORER, PER, and FER flags in SSR. After performing the appropriate error processing, be sure to clear the ORER, PER, and FER flags to 0. Reception cannot be resumed if any of these flags is set to 1. In the case of a framing error, a break can be detected by reading the value of the input port corresponding to the RXDn pin.

[4] Read the receive data in RDR once in the RXI interrupt processing routine.

[5] Serial reception continuation procedure:
To continue serial reception, before the stop bit of the current frame is received, read data from RDR in the RXI interrupt processing routine. The RDR data can also be read by activating the DTC.

Figure 22.9 Example of Serial Reception Flowchart (1) (Asynchronous Mode)

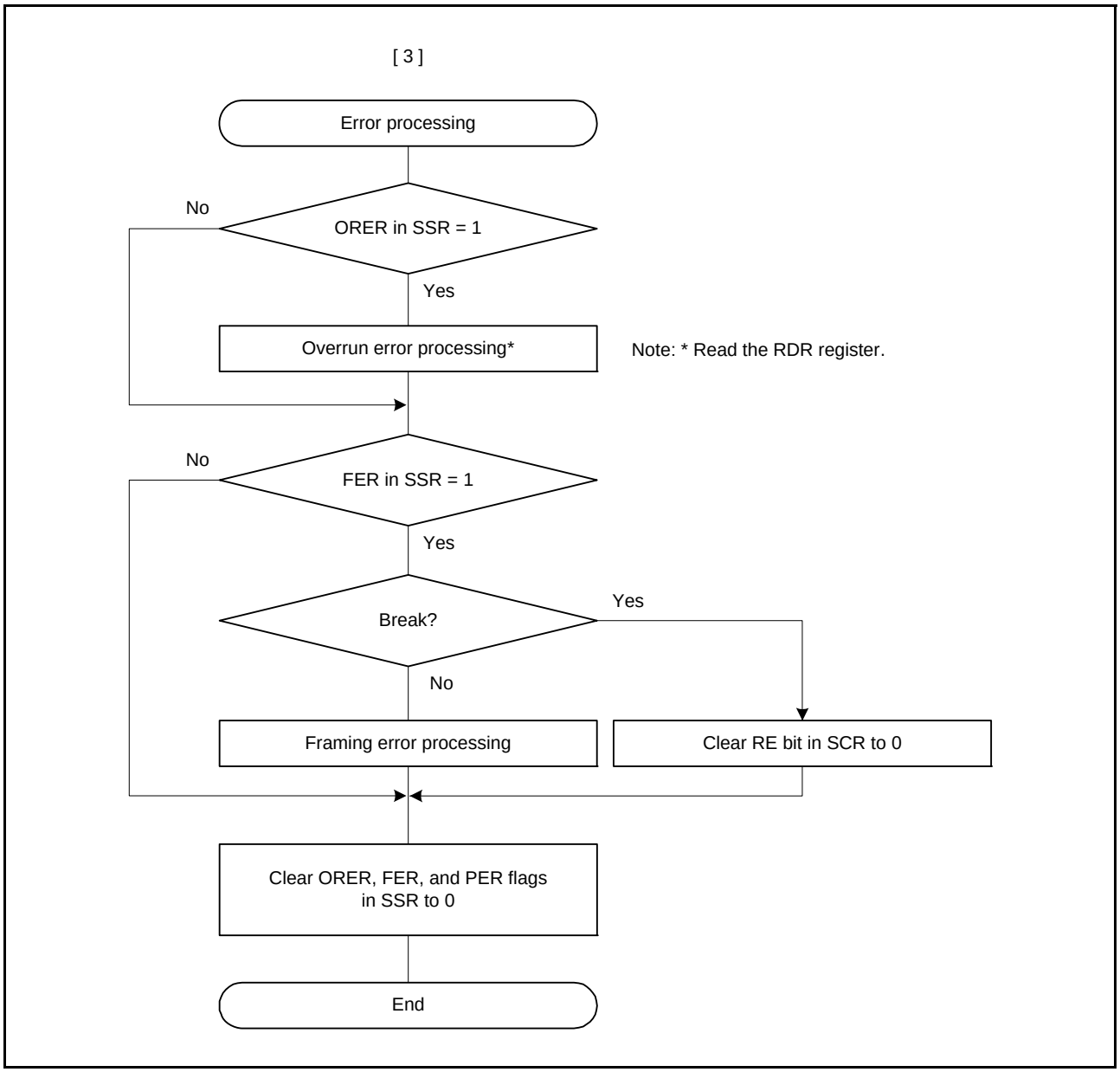


Figure 22.10 Example of Serial Reception Flowchart (2) (Asynchronous Mode)

22.2.3 Multi-Processor Communications Function

Using the multi-processor communication functions enables to transmit and receive data by sharing a communication line between multiple processors by using asynchronous serial communication in which the multi-processor bit is added. In multi-processor communication, a unique ID code is allocated to each receiving station. Serial communication cycles consist of an ID transmission cycle to specify the receiving station and a data transmission cycle to transmit data to the specified receiving station. The multi-processor bit is used to distinguish between the ID transmission cycle and the data transmission cycle. When the multi-processor bit is set to 1, it indicates the ID transmission cycle and when the multi-processor bit is set to 0, it indicates the data transmission cycle. Figure 22.11 shows an example of communication between processors by using a multi-processor format. First, a transmitting station transmits communication data in which the multi-processor bit set to 1 is added to the ID code of the receiving station. Next, the transmitting station transmits the communication data in which the multi-processor bit set to 0 is added to the transmission data. Upon receiving the communication data in which the multi-processor bit is set to 1, the receiving station compares the received ID with the ID of the receiving station itself and if the two match, receives the communication data that is subsequently transmitted. If the received ID does not match with the ID of the receiving station, the receiving station skips the communication data until again receiving the communication data in which the multi-processor bit is set to 1.

For supporting this function, the SCI provides the MPIE bit in SCR. When the MPIE bit is set to 1, transfer of reception data from the RSR to the RDR, detection of a reception error, and setting the respective status flags ORER and FER in SSR are disabled until reception of data in which the multi-processor bit is set to 1. Upon receiving a reception character in which the multi-processor bit is set to 1, the MPB bit in SSR is set to 1 and the MPIE bit in SCR is automatically cleared, thus returning to a normal reception operation. During this time, an RXI interrupt is generated if the RIE bit in SCR is set.

As the transmitting in the multi-processor mode, in the ID transmission cycle and the data transmission cycle, the data should be transmitted with the SSR.MPBT bit to 1 and 0, respectively.

When the multi-processor format is specified, specification of the parity bit is disabled. Apart from this, there is no difference from the operation in the normal asynchronous mode. A clock which is used for the multi-processor communication is also the same as the clock used in the normal asynchronous mode.

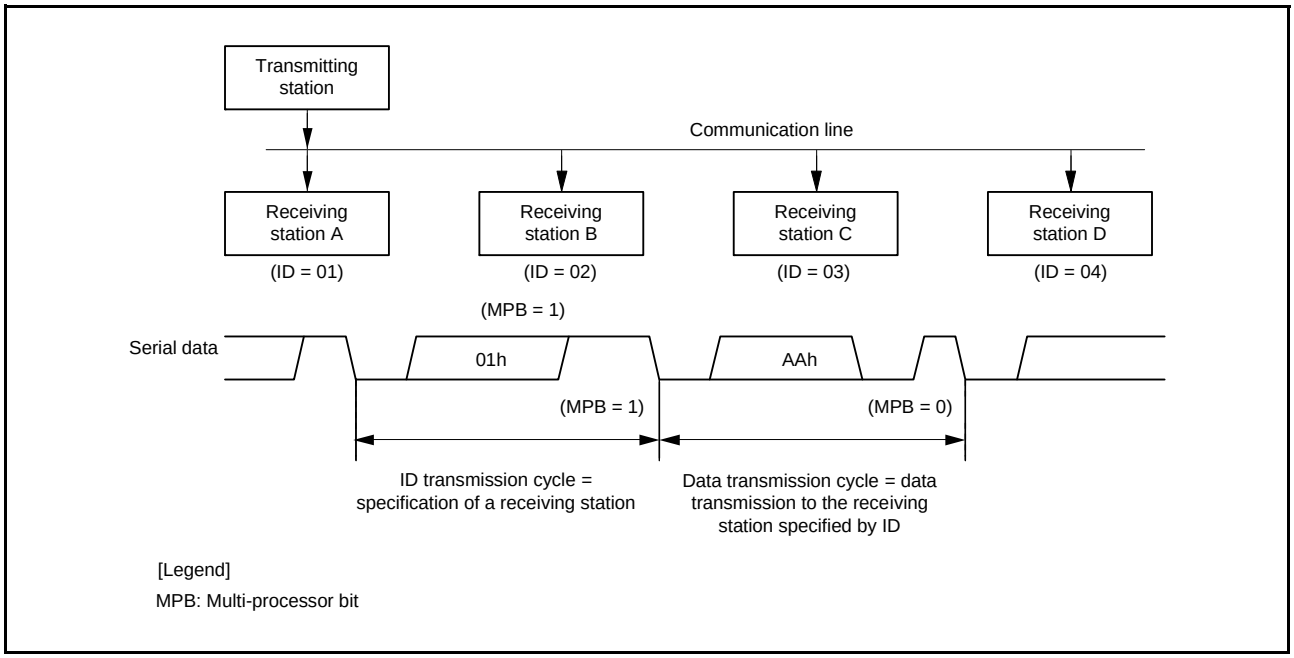


Figure 22.11 An Example of Communication using the Multi-Processor Format (Example of Transmission of Data AAh to Receiving Station A)

22.2.3.1 Multi-Processor Serial Data Transmission

Figure 22.12 is a sample flowchart of multi-processor data transmission. In the ID transmission cycle, the ID should be transmitted with the MPBT bit in SSR set to 1. In the data transmission cycle, the data should be transmitted with the MPBT bit set to 0. The other operations are the same as the operations in asynchronous mode.

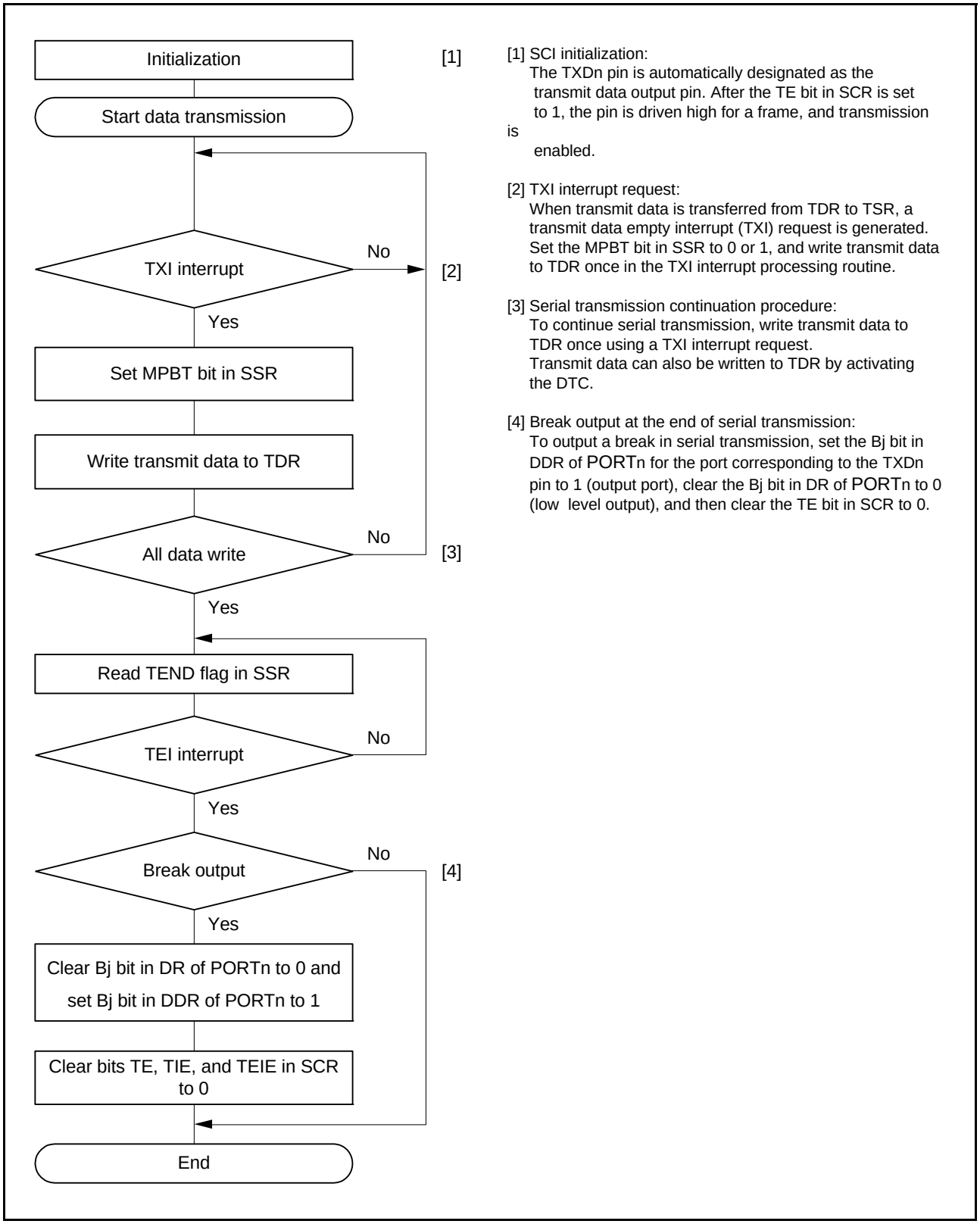


Figure 22.12 Example of Multi-Processor Serial Transmission Flowchart

22.2.3.2 Multi-Processor Serial Data Reception

Figure 22.14 and Figure 22.15 are sample flowcharts of multi-processor data reception. When the MPIE bit in SCR is set to 1, transmitting the receive data to RDR from RSR is skipped until reception of the communication data in which the multi-processor bit is set to 1. When the communication data in which the multi-processor bit is set to 1 is received, the received data is transferred to RDR. During this time, the RXI interrupt request is generated. The other operations are the same as the operations in asynchronous mode.
Figure 22.13 is the example of operation for reception.

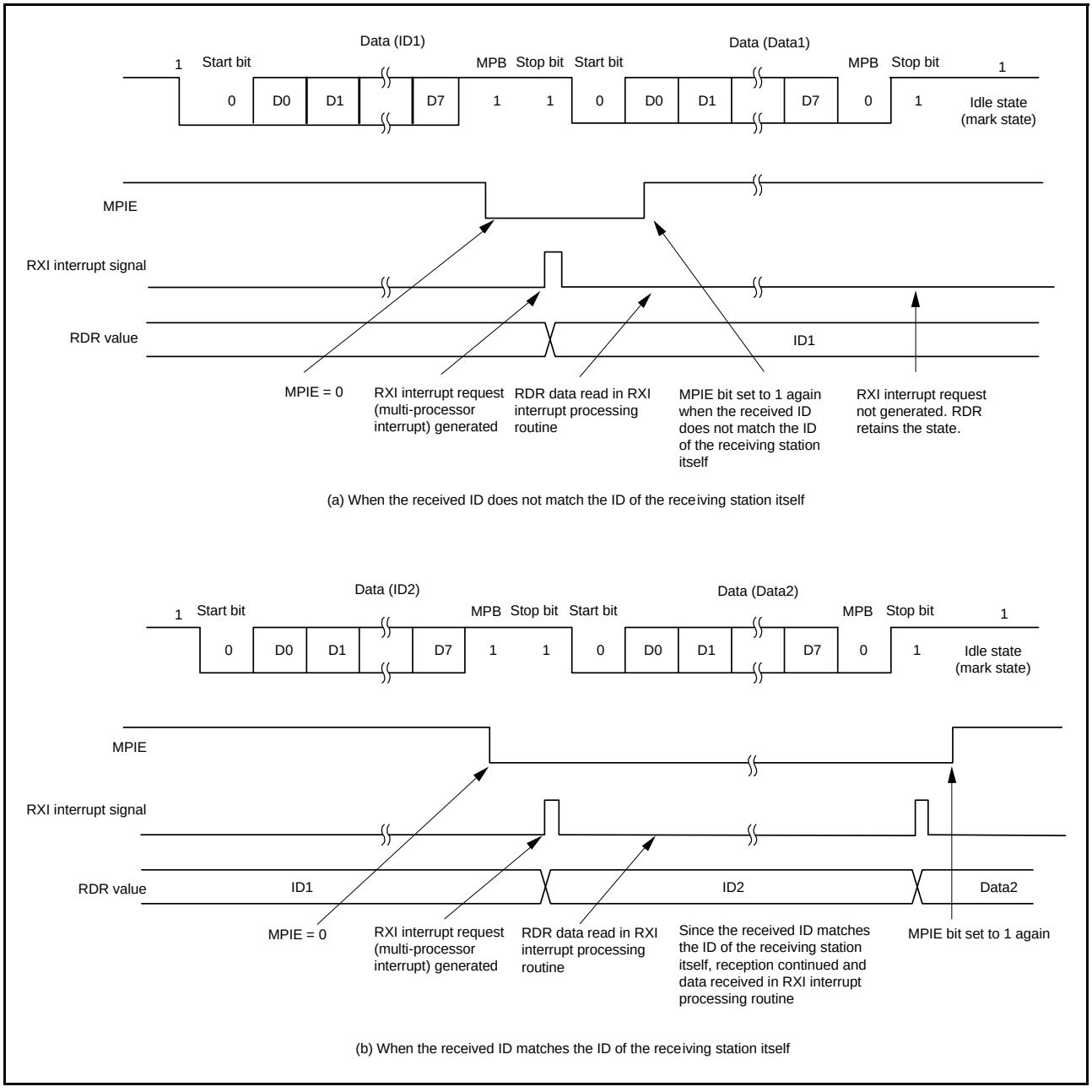
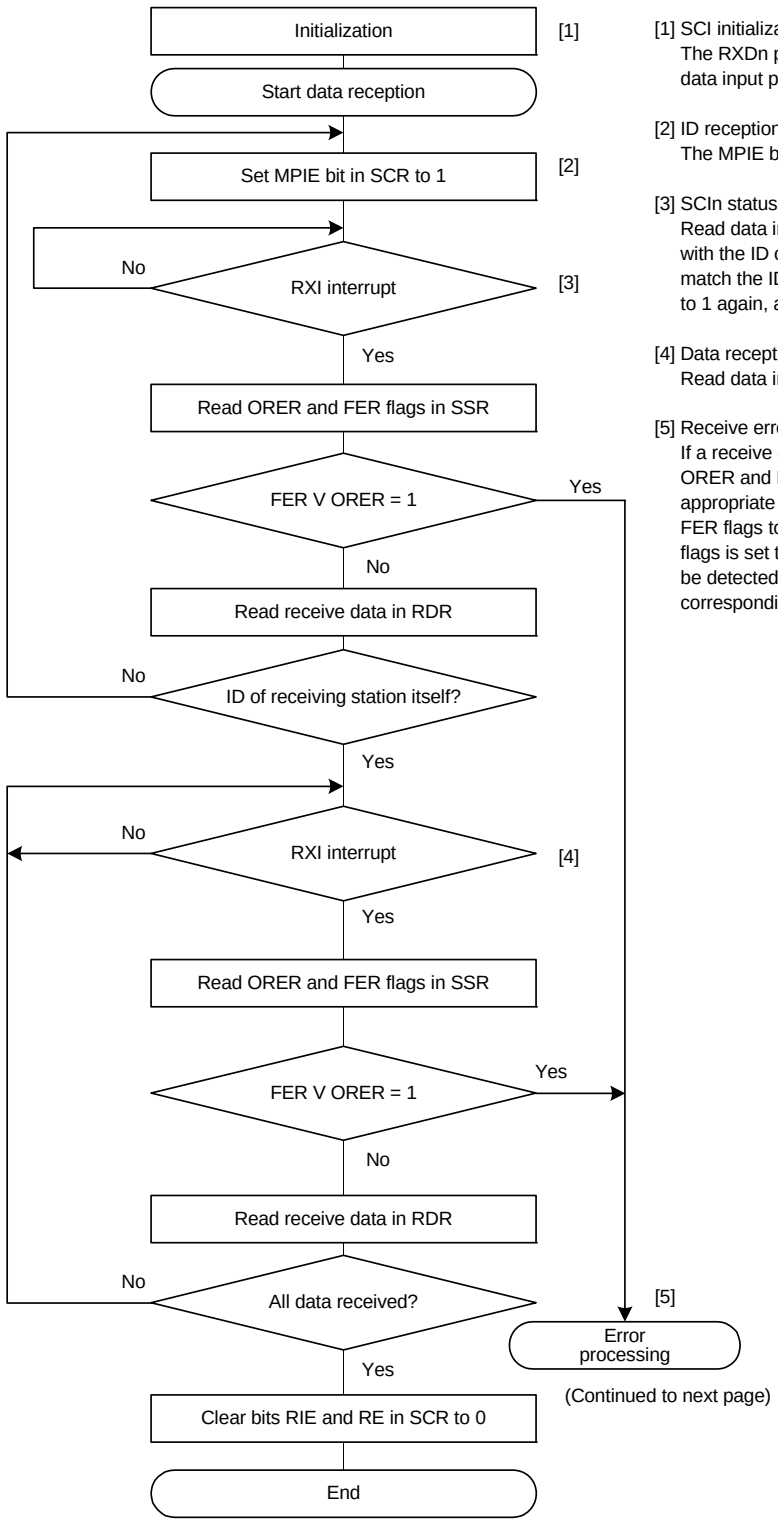


Figure 22.13 Example of SCI Reception (8-Bit Data/Multi-Processor Bit/One Stop Bit)



[1] SCI initialization:
The RXDn pin is automatically designated as the receive data input pin.

[2] ID reception cycle:
The MPIE bit in SCR is set to 1 , and wait for ID reception.

[3] SCIn status confirmation and reception and comparison of ID:
Read data in RDR at the first RXI interrupt, and compare it with the ID of the receiving station itself. If the ID does not match the ID of the receiving station itself, set the MPIE bit to 1 again, and wait for another RXI interrupt.

[4] Data reception at an RXI interrupt:
Read data in RDR once in the RXI interrupt routine.

[5] Receive error processing and break detection:
If a receive error occurs, an error is identified by reading the ORER and FER flags in SSR. After performing the appropriate error processing, be sure to clear the ORER and FER flags to 0. Reception cannot be resumed if any of these flags is set to 1. In the case of a framing error, a break can be detected by reading the value of the input port corresponding to the RXD pin.

Figure 22.14 Example of Multi-Processor Serial Reception Flowchart (1)

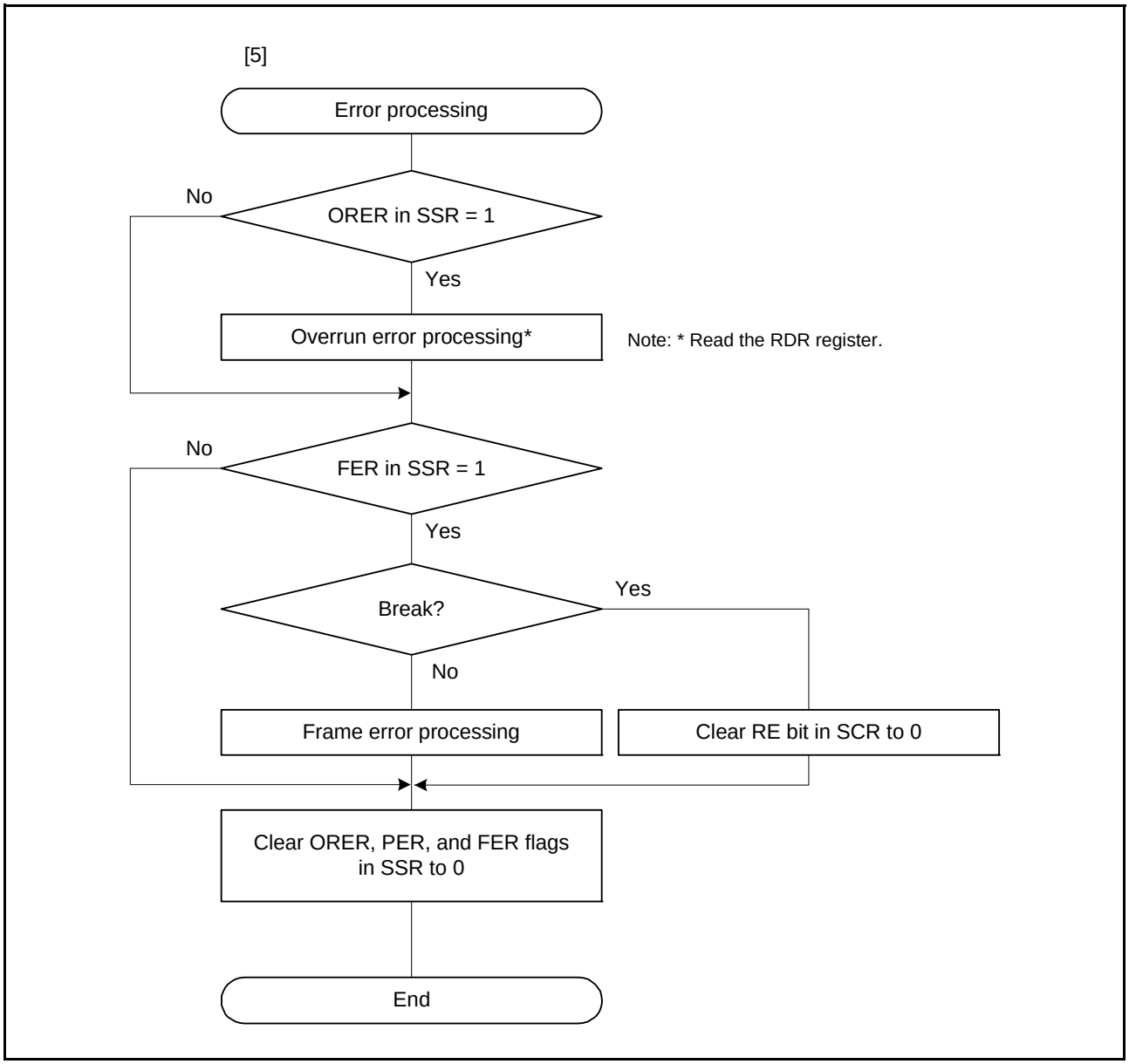


Figure 22.15 Example of Multi-Processor Serial Reception Flowchart (2)

22.2.4 Operation in Clock Synchronous Mode

Figure 22.16 shows the data format for clock synchronous serial data communications.
In clock synchronous mode, data is transmitted or received in synchronization with clock pulses. One character in transfer data consists of 8-bit data. In clock synchronous mode, no parity bit can be added.
In data transmission, the SCI outputs data from one falling edge of the synchronization clock to the next. In data reception, the SCI receives data in synchronization with the rising edge of the synchronization clock. After 8-bit data is output, the transmission line holds the MSB output state.
Inside the SCI, the transmitter and receiver are independent units, enabling full-duplex communications by use of a common clock. Both the transmitter and the receiver also have a double-buffered structure, so that the next transmit data can be written during transmission or the previous receive data can be read during reception, enabling continuous data transfer.

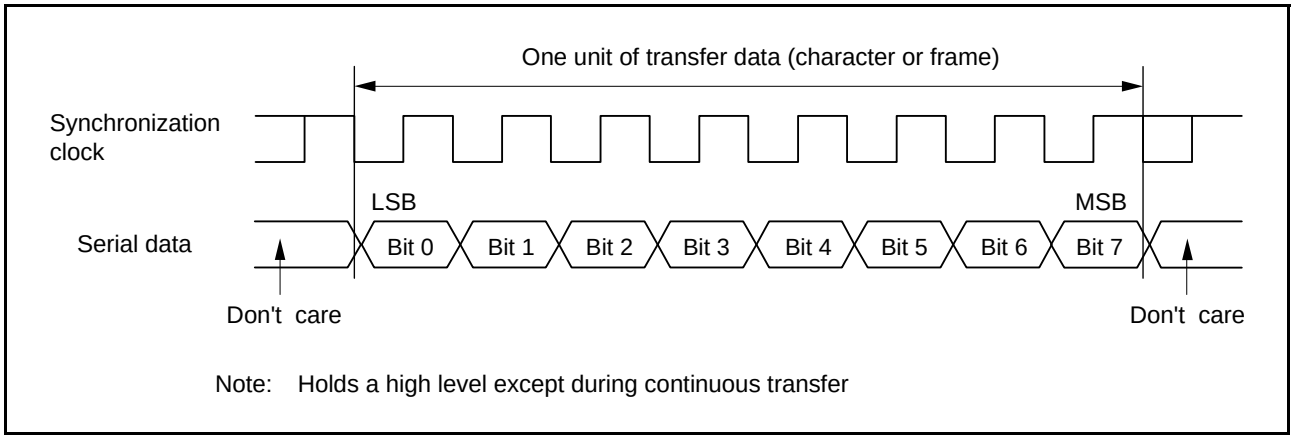


Figure 22.16 Data Format in Clock Synchronous Serial Communications (LSB-First)

22.2.4.1 Clock

Either an internal clock generated by the on-chip baud rate generator or an external synchronization clock input at the SCKn pin can be selected, according to the setting of the CKE[1:0] bits in SCR.
When the SCI is operated on an internal clock, the synchronization clock is output from the SCKn pin. Eight synchronization clock pulses are output in the transfer of one character, and when no transfer is performed the clock is held high. However, the synchronization clock is continuously output only during data reception until an overrun error occurs or the RE bit in SCR is cleared to 0.

22.2.4.2 SCI Initialization (Clock Synchronous Mode)

Before transmitting and receiving data, start by writing the initial value "00h" to the SCR and then continue through the procedure for SCI given in the sample flowchart (Figure 22.17). Whenever the operating mode or transfer format is changed, the SCR must be initialized before the change is made.
Note that clearing the SCR.RE bit to 0 initializes neither the ORER, FER, and PER flags in SSR nor RDR.
Moreover, note that switching the value of the SCR.TE bit from 1 to 0 or 0 to 1 while the SCR.TIE bit is 1 leads to the generation of a TXI interrupt request.

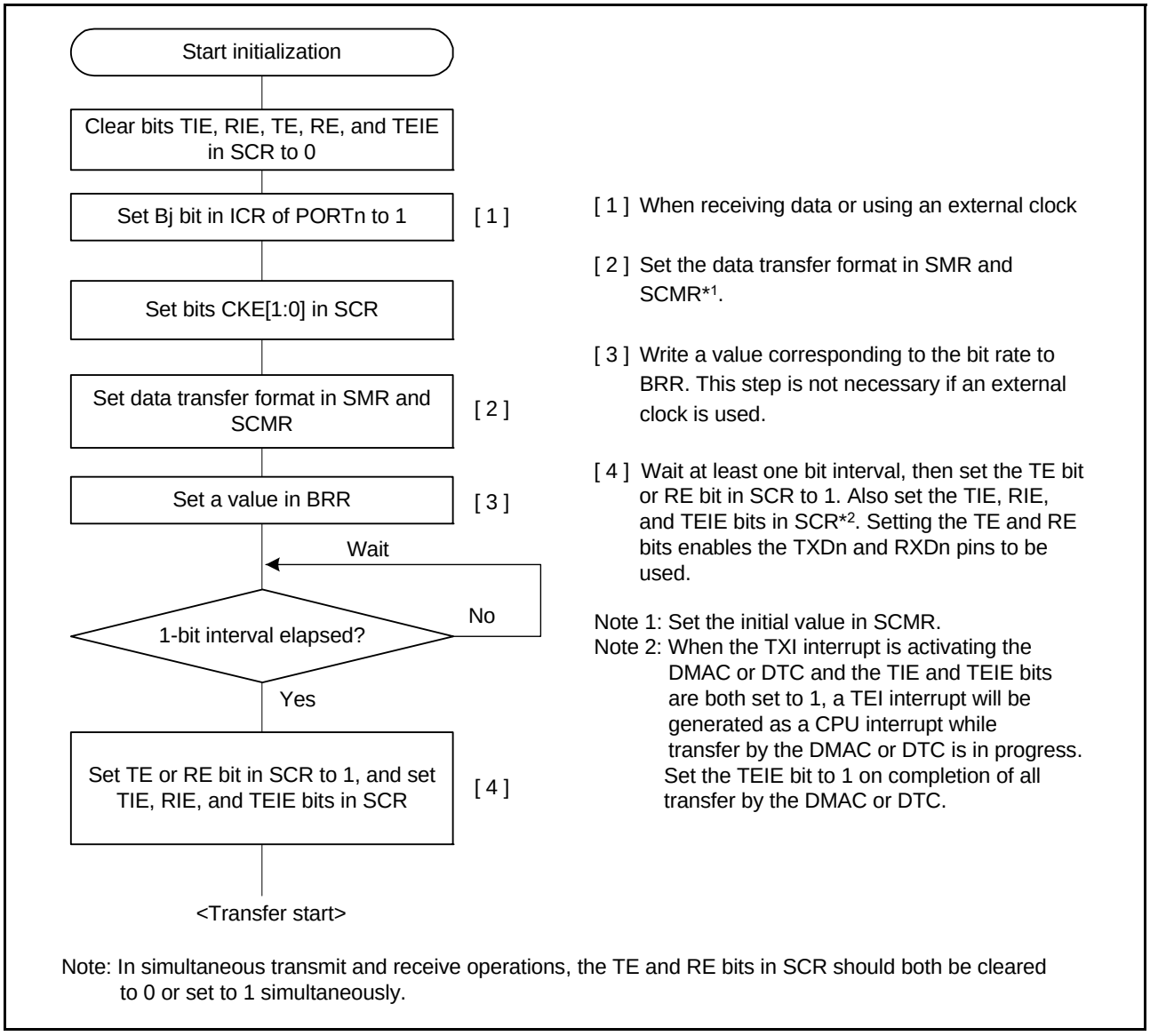


Figure 22.17 Example of SCI Initialization Flowchart (Clock Synchronous Mode)

22.2.4.3 Serial Data Transmission (Clock Synchronous Mode)

Figure 22.18 shows an example of the operation for serial transmission in clock synchronous mode.
In serial data transmission, the SCI operates as described below.

1. The SCI transfers data from TDR to TSR when data is written to TDR in the TXI interrupt processing routine. The TXI interrupt request at the beginning of transmission is generated when the TE bit in SCR is set to 1 after the TIE bit in SCR is set to 1 or when these two bits are set to 1 simultaneously by a single instruction.
2. After transferring data from TDR to TSR, the SCI starts transmission. When the TIE bit is set to 1 at this time, a TXI interrupt request is generated. Continuous transmission is enabled by writing the next transmit data to TDR in this TXI interrupt processing routine before transmission of the current transmit data has finished.
3. 8-bit data is sent from the TXDn pin in synchronization with the output clock when clock output mode has been specified and in synchronization with the input clock when use of an external clock has been specified.
4. The SCI checks for updating of (writing to) the TDR at the time of the last bit output.
5. When TDR is updated, the next transmit data is transferred from TDR to TSR, and serial transmission of the next frame is started.
6. If TDR is not updated, set the SSR flag in TEND to 1 and the TXDn pin retains the output state of the last bit. If the TEIE bit in SCR is 1 at this time, a TEI interrupt request is generated. The SCKn pin is held high.

Figure 22.19 shows a sample flowchart of serial data transmission.
Transmission will not start while a receive error flag (ORER, FER, or PER in SSR) is set to 1. Be sure to clear the receive error flags to 0 before starting transmission. Note that clearing the RE bit in SCR to 0 does not clear the receive error flags.

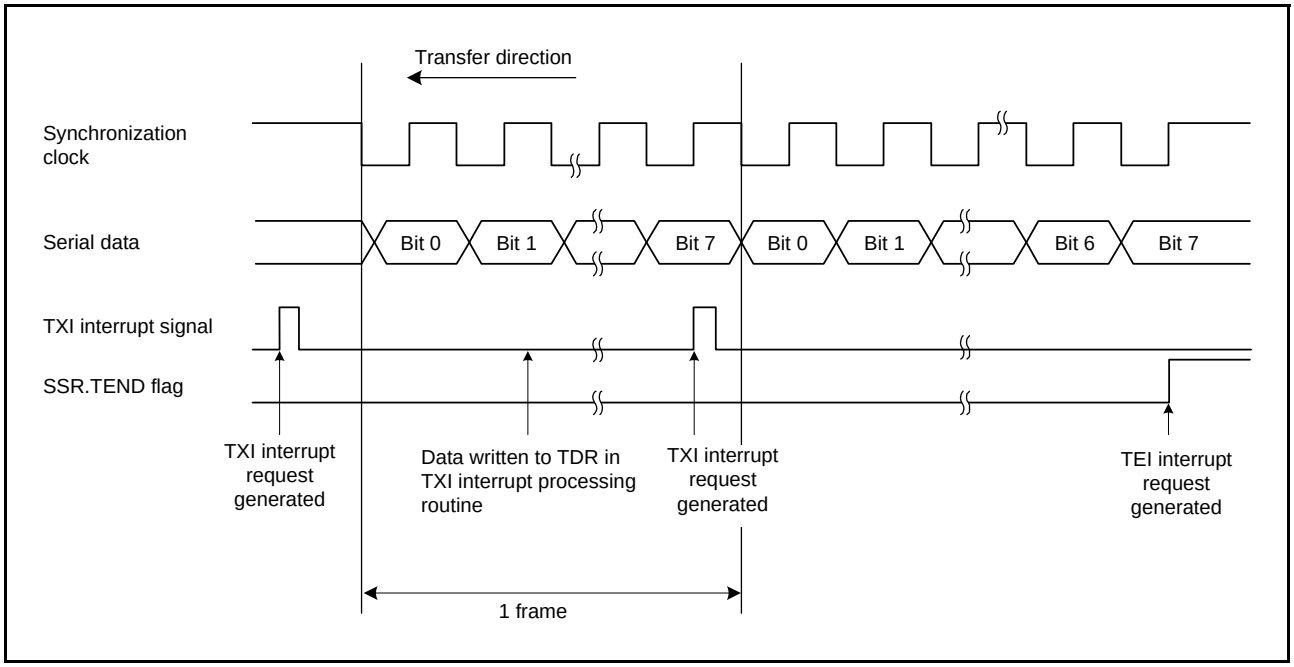
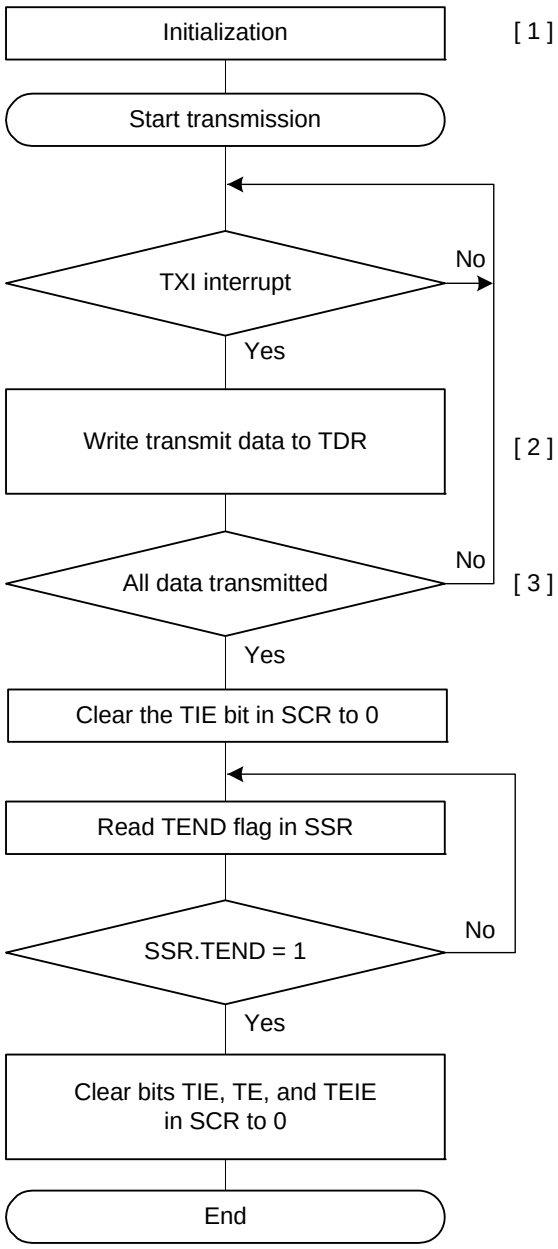


Figure 22.18 Example of Operation for Serial Transmission in Clock Synchronous Mode



[1] SCIn initialization:
The TXDn pin is automatically designated as the transmit data output pin.

[2] Transmit data write to TDR by a TXI interrupt request:
When transmit data is transferred from TDR to TSR, a transmit data empty interrupt (TXI) request is generated.
Transmit data is written to TDR once upon accepting a transmit data empty interrupt (TXI) request.

[3] Serial transmission continuation procedure:
To continue serial transmission, write transmit data to TDR upon accepting a transmit data empty interrupt (TXI) . Transmit data can also be written to TDR by initiating the DTC when a TXI interrupt request is accepted.

Note: When the external clock is selected (when bit SCR.CKE[1] = 1), the SSR.TEND flag becomes 1 on the rising edge of the SCK signal for the final bit.
Take care because quickly clearing the SCR.TE bit to 0 can leave the receiving device with insufficient hold time for the received data.

Figure 22.19 Example of Serial Transmission Flowchart (Clock Synchronous Mode)

22.2.4.4 Serial Data Reception (Clock Synchronous Mode)

Figure 22.20 shows an example of SCI operation for serial reception in clock synchronous mode.
In serial data reception, the SCI operates as described below.

1. The SCI performs internal initialization and starts receiving data in synchronization with a synchronization clock input or output, and stores the receive data in RSR.
2. If an overrun error occurs, the ORER bit in SSR is set to 1. If the RIE bit in SCR is 1 at this time, an ERI interrupt request is generated. Receive data is not transferred to RDR.
3. When reception finishes successfully, receive data is transferred to RDR. If the RIE bit in SCR is 1 at this time, an RXI interrupt request is generated. Continuous reception is enabled by reading the receive data transferred to RDR in this RXI interrupt processing routine before reception of the next receive data is completed.

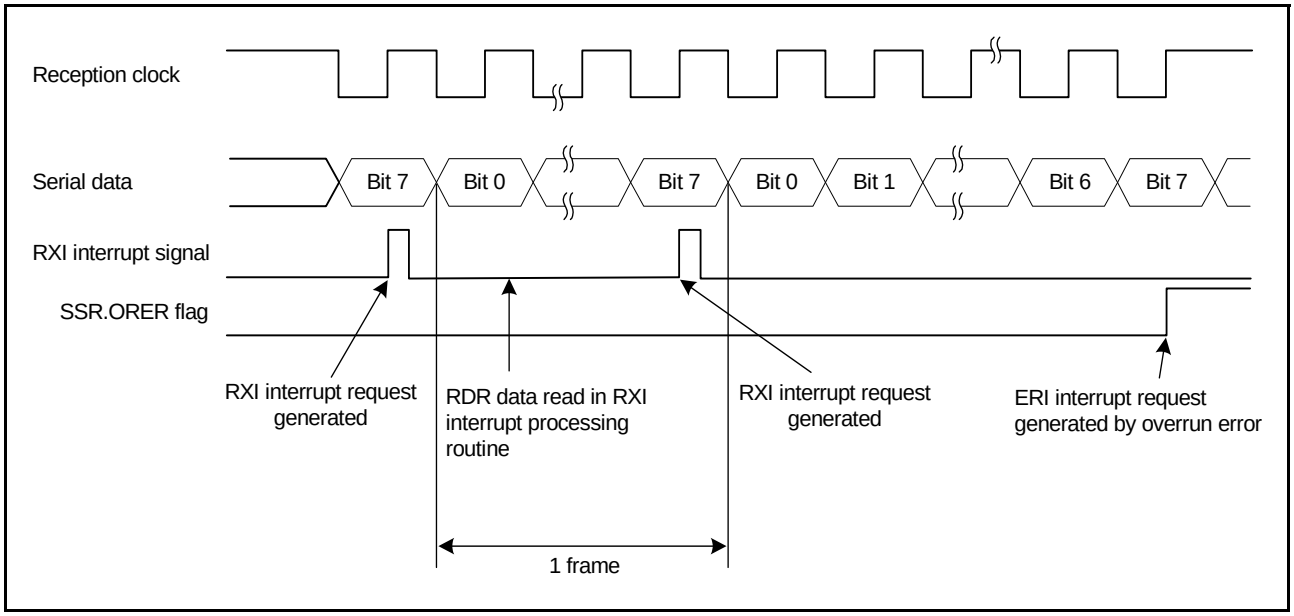


Figure 22.20 Example of Operation for Serial Reception in Clock Synchronous Mode

Data transfer cannot be resumed while a receive error flag is 1. Accordingly, clear the ORER, FER, and PER flags in SSR to 0 before resuming reception. Moreover, be sure to read the RDR during overrun error processing.
Figure 22.21 shows a sample flowchart for serial data reception.

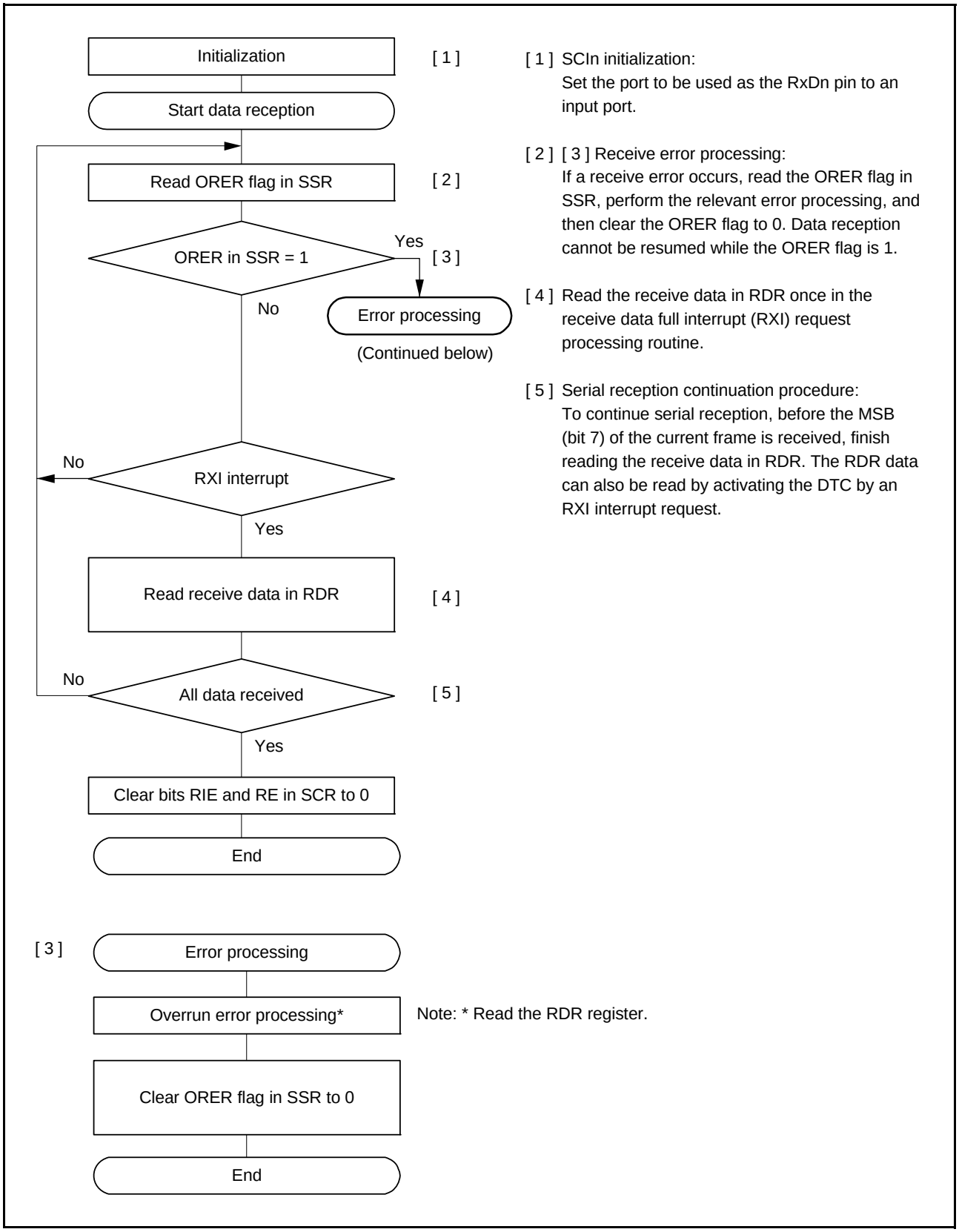


Figure 22.21 Example of Serial Reception Flowchart (Clock Synchronous Mode)

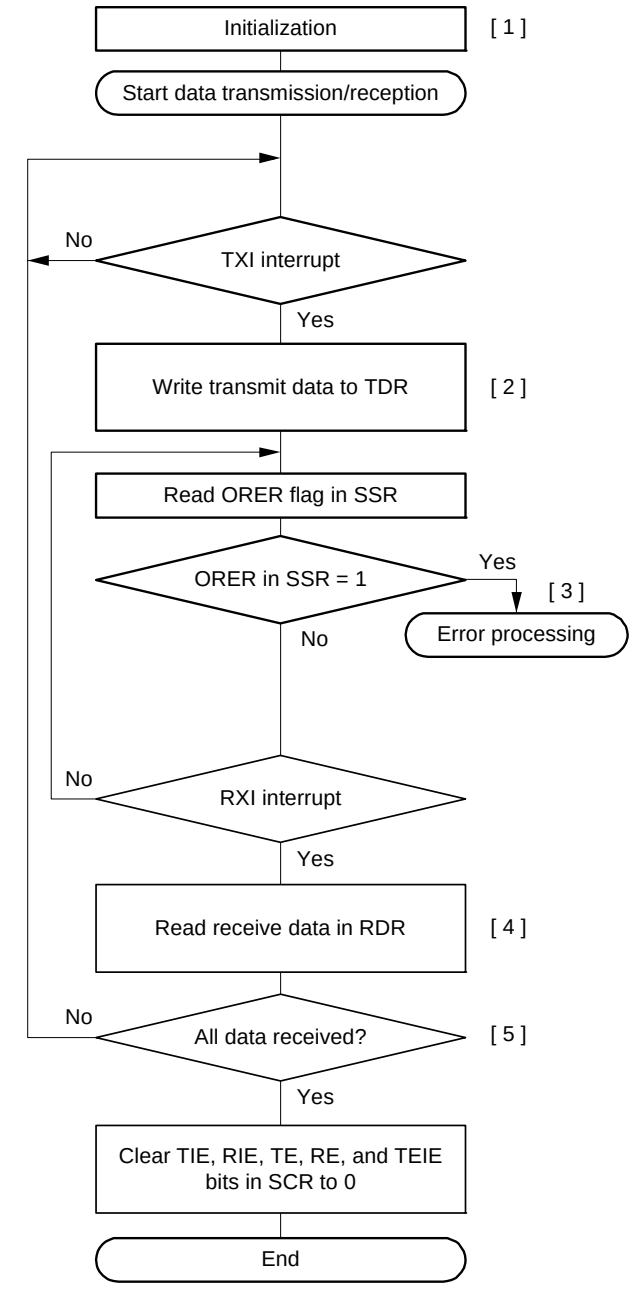
22.2.5 Simultaneous Serial Data Transmission and Reception (Clock Synchronous Mode)

Figure 22.22 shows a sample flowchart for simultaneous serial transmit and receive operations in clock synchronous mode.

After initializing the SCI, the following procedure should be used for simultaneous serial data transmit and receive operations.

To switch from transmit mode to simultaneous transmit and receive mode, check that the SCI has finished transmission by reading that the TEND flag in SSR is 1, and then initialize the SCR register. Then set the TIE, RIE, TE, RE, and TEIE bits in SCR to 1 simultaneously by a single instruction.

To switch from receive mode to simultaneous transmit and receive mode, check that the SCI has finished reception, and then clear the RIE and RE bits to 0. Then check that the receive error flags (ORER, FER, and PER in SSR) are 0, and then set the TIE, RIE, TE, RE, and TEIE bits in SCR to 1 simultaneously by a single instruction.



[1] SCIn initialization:
The TXDn pin is designated as the transmit data output pin, and the RXDn pin is designated as the receive data input pin, enabling simultaneous transmit and receive operations.

[2] Transmit data write:
Write transmit data to TDR once in the TXI interrupt request processing routine.

[3] Receive error processing:
If a receive error occurs, read the ORER flag in SSR, perform the relevant error processing, and then clear the ORER flag to 0. Data reception cannot be resumed while the ORER flag is 1.

[4] Receive data read:
Read the receive data in RDR once in the RXI interrupt request processing routine.

[5] Serial transmission/reception continuation procedure:
To continue serial transmission and reception, before the MSB (bit 7) of the current frame is received, finish reading the receive data in RDR by the RXI interrupt. Also, before the MSB (bit 7) of the current frame is transmitted, write data to TDR by the TXI interrupt.
Transmit data can also be written to TDR by activating the DTC by a transmit data empty interrupt (TXI) request. Similarly, the RDR data can also be read by activating the DTC by a receive data full interrupt (RXI) request.

Note: When switching from transmit or receive operation to simultaneous transmit and receive operations, first clear the TIE, RIE, TE, RE, and TEIE bits in SCR to 0, and then set these bits to 1 simultaneously.

Figure 22.22 Example of Simultaneous Serial Transmission and Reception Flowchart (Clock Synchronous Mode)

22.3 Smart Card Interface Mode

As an extended function of the SCI, it is capable of operating in compliance with ISO/IEC 7816-3 (Identification Cards) as an interface with smart cards (IC cards).
The SCI runs in smart-card interface mode when the setting of the SCMR.SMIF bit is "1".

22.3.1 Register Descriptions

Table 22.14 lists the registers of the SMCI. Some registers (TDR, RDR, and SCMR) have same functions in serial communications interface mode and smart card interface mode. Therefore, for the descriptions on the TDR, RDR, and SCMR registers, see section 22.2.1, Register Descriptions.

Table 22.14 Registers of SMCI

Channel	Register Name	Symbol	Value after Reset	Address	Access Size
SMCI0	Serial mode register	SMR	00h	0008 8240h	8
	Bit rate register	BRR	FFh	0008 8241h	8
	Serial control register	SCR	00h	0008 8242h	8
	Transmit data register	TDR	FFh	0008 8243h	8
	Serial status register	SSR	84h	0008 8244h	8
	Receive data register	RDR	00h	0008 8245h	8
	Smart card mode register	SCMR	F2h	0008 8246h	8
	Serial extended mode register	SEMR	00h	0008 8247h	8
SMCI1	Serial mode register	SMR	00h	0008 8248h	8
	Bit rate register	BRR	FFh	0008 8249h	8
	Serial control register	SCR	00h	0008 824Ah	8
	Transmit data register	TDR	FFh	0008 824Bh	8
	Serial status register	SSR	84h	0008 824Ch	8
	Receive data register	RDR	00h	0008 824Dh	8
	Smart card mode register	SCMR	F2h	0008 824Eh	8
	Serial extended mode register	SEMR	00h	0008 824Fh	8
SMCI2	Serial mode register	SMR	00h	0008 8250h	8
	Bit rate register	BRR	FFh	0008 8251h	8
	Serial control register	SCR	00h	0008 8252h	8
	Transmit data register	TDR	FFh	0008 8253h	8
	Serial status register	SSR	84h	0008 8254h	8
	Receive data register	RDR	00h	0008 8255h	8
	Smart card mode register	SCMR	F2h	0008 8256h	8
	Serial extended mode register	SEMR	00h	0008 8257h	8

22.3.1.1 Serial Mode Register (SMR)

Address: SMCI0.SMR 0008 8240h, SMCI1.SMR 0008 8248h, SMCI2.SMR 0008 8250h

	b7	b6	b5	b4	b3	b2	b1	b0
	GM	BLK	PE	PM	BCP[1:0]		CKS[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Function	R/W
b1, b0	CKS[1:0]	Clock Select	b1 b0 00: PCLK clock (n = 0)*1 01: PCLK/4 clock (n = 1)*1 10: PCLK/16 clock (n = 2)*1 11: PCLK/64 clock (n = 3)*1	R/W*3
b3, b2	BCP[1:0]	Base Clock Pulse	Selects the number of base clock cycles in combination with the BCP2 bit in SCMR. Setting values in BCP2 bit in SCMR and BCP[1:0] bits in SMR: BCP2 b3 b2 0 0 0: 93 clock cycles (S = 93)*2 0 0 1: 128 clock cycles (S = 128)*2 0 1 0: 186 clock cycles (S = 186)*2 0 1 1: 512 clock cycles (S = 512)*2 1 0 0: 32 clock cycles (S = 32)*2 (Initial value) 1 0 1: 64 clock cycles (S = 64)*2 1 1 0: 372 clock cycles (S = 372)*2 1 1 1: 256 clock cycles (S = 256)*2	R/W*3
b4	PM	Parity Mode	(Valid only when the PE bit is 1 in asynchronous mode) 0: Selects even parity 1: Selects odd parity	R/W*3
b5	PE	Parity Enable	(Valid only in asynchronous mode) When this bit is set to 1, the parity bit is added to transmit data before transmission, and the parity bit is checked in reception. Set this bit to 1 in smart card interface mode.	R/W*3
b6	BLK	Block Transfer Mode	0: Normal mode operation 1: Block transfer mode operation	R/W*3
b7	GM	GSM Mode	0: Normal mode operation 1: GSM mode operation	R/W*3

Note 1. n is the decimal notation of the value of n in BRR (see section 22.3.1.4, Bit Rate Register (BRR).
Note 2. S is the value of S in BRR (see section 22.3.1.4, Bit Rate Register (BRR).
Note 3. Writable only when TE in SCR = 0 and RE in SCR = 0 (both serial transmission and reception are disabled).

SMR is used to set the SCI's serial transfer format and select the clock source for the on-chip baud rate generator.

CKS[1:0] Bits (Clock Select)

These bits select the clock source for the on-chip baud rate generator.
For the relationship between the settings of these bits and the baud rate, see section 22.3.1.4, Bit Rate Register (BRR).

BCP[1:0] Bits (Base Clock Pulse)

These bits select the number of base clock cycles in a 1-bit data transfer time in smart card interface mode.
Set these bits in combination with the BCP2 bit in SCMR.
For details, see section 22.3.3.2, Receive Data Sampling Timing and Reception Margin.

PM Bit (Parity Mode)

Selects the parity mode for transmission and reception (even or odd).
For details on the usage of this bit in smart card interface mode, see section 22.3.3, Data Format (Except in Block Transfer Mode).

PE Bit (Parity Enable)

Set the PE bit to 1.
The parity bit is added to transmit data before transmission, and the parity bit is checked in reception.

BLK Bit (Block Transfer Mode)

Setting this bit to 1 allows block transfer mode operation.
For details, see section 22.3.3.1, Block Transfer Mode.

GM Bit (GSM Mode)

Setting this bit to 1 allows GSM mode operation.
In GSM mode, the SSR.TEND flag set timing is put forward to 11.0 etu (elementary time unit = 1-bit transfer time) from the start and the clock output control function is appended. For details, see section 22.3.3.4, Serial Data Transmission (Except in Block Transfer Mode) and section 22.3.3.6, Clock Output Control.

22.3.1.2 Serial Control Register (SCR)

Address: SMCI0.SCR 0008 8242h, SMCI1.SCR 0008 824Ah, SMCI2.SCR 0008 8252h

	b7	b6	b5	b4	b3	b2	b1	b0
	TIE	RIE	TE	RE	MPIE	TEIE	CKE[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Function	R/W
b1, b0	CKE[1:0]	Clock Enable	• When GM in SMR = 0 b1 b0 0 0: Output disabled (SCKn pin functions as I/O port.) 0 1: Clock output 1 0: (Setting prohibited) 1 1: (Setting prohibited) • When GM in SMR = 1 0 0: Output fixed low 0 1: Clock output 1 0: Output fixed high 1 1: Clock output	R/W*1
b2	TEIE	Transmit End Interrupt Enable	This bit should be 0 in smart card interface mode.	R/W
b3	MPIE	Multi-Processor Interrupt Enable	This bit should be 0 in smart card interface mode.	R/W
b4	RE	Receive Enable	0: Serial reception is disabled 1: Serial reception is enabled	R/W*2
b5	TE	Transmit Enable	0: Serial transmission is disabled 1: Serial transmission is enabled	R/W*2
b6	RIE	Receive Interrupt Enable	0: RXI and ERI interrupt requests are disabled 1: RXI and ERI interrupt requests are enabled	R/W
b7	TIE	Transmit Interrupt Enable	0: A TXI interrupt request is disabled 1: A TXI interrupt request is enabled	R/W

Note 1. Writable only when TE = 0 and RE = 0.
Note 2. While the SMR.CM bit is 1, 1 can be written only when TE = 0 and RE = 0. After setting TE or RE to 1, only 0 can be written in TE and RE.

SCR is a register that enables/disables the SCI transfer operations and the interrupt requests and selects the transfer clock source. For details on interrupt sources, see section 22.5, Interrupt Sources.

CKE[1:0] Bits (Clock Enable)

These bits control the clock output from the SCKn pin.
In GSM mode, clock output can be dynamically switched. For details, see section 22.3.3.6, Clock Output Control.

TEIE Bit (Transmit End Interrupt Enable)

This bit should be 0 in smart card interface mode.

MPIE Bit (Multi-Processor Interrupt Enable)

This bit should be 0 in smart card interface mode.

RE Bit (Receive Enable)

Enables or disables serial reception.

When this bit is set to 1, serial reception is started by detecting the start bit. Note that SMR should be set prior to setting the RE bit to 1 in order to designate the reception format.

Even if reception is halted by clearing the RE bit to 0, the ORER, FER, and PER flags in SSR are not affected and the previous value is retained.

TE Bit (Transmit Enable)

Enables or disables serial transmission.

When this bit is set to 1, serial transmission is started by writing transmit data to TDR. Note that SMR should be set prior to setting the TE bit to 1 in order to designate the transmission format.

RIE Bit (Receive Interrupt Enable)

Enables or disables RXI and ERI interrupt requests.

An RXI interrupt request is disabled by clearing the RIE bit to 0.

An ERI interrupt request can be cancelled by reading 1 from the ORER, FER, or PER flag in SSR and then clearing the flag to 0, or clearing the RIE bit to 0.

TIE Bit (Transmit Interrupt Enable)

Enables or disables notification of a TXI interrupt request.

Notification of a TXI interrupt request is disabled by clearing the TIE bit to 0.

22.3.1.3 Serial Status Register (SSR)

Address: SMCI0.SSR 0008 8244h, SMCI1.SSR 0008 824Ch, SMCI2.SSR 0008 8254h

	b7	b6	b5	b4	b3	b2	b1	b0
	TDRE	RDRF	ORER	ERS	PER	TEND	MPB	MPBT
Value after reset:	1	0	0	0	0	1	0	0

Bit	Symbol	Bit Name	Function	R/W
b0	MPBT	Multi-Processor Bit Transfer	This bit should be set to 0 in smart card interface mode.	R/W
b1	MPB	Multi-Processor	This bit is not used in smart card interface mode. It should be set to 0.	R
b2	TEND	Transmit End Flag	0: A character is being transmitted. 1: Character transfer has been completed.	R
b3	PER	Parity Error Flag	0: No parity error occurred 1: A parity error has occurred	R/(W)*1
b4	ERS	Error Signal Status Flag	0: Low error signal not responded 1: Low error signal responded	R/(W)* 1
b5	ORER	Overrun Error Flag	0: No overrun error occurred 1: An overrun error has occurred	R/(W)* 1
b6	RDRF	Receive Data Full Flag	0: When data is transferred from RDR 1: When data has been received normally, and transferred from RSR to RDR	R/(W) *2
b7	TDRE	Transmit Data Empty Flag	0: When data is transferred to TDR 1: When data is transferred from TDR to TSR	R/(W) *2

Note 1. Only 0 can be written to this bit after reading it as 1, to clear the flag.
Note 2. Write 1 when writing is necessary.

SSR is a register containing status flags of the SCI.

MPBT Bit (Multi-Processor Bit Transfer)

This bit should be set to 0 in smart card interface mode.

MPB Bit (Multi-Processor)

This bit is not used in smart card interface mode. It should be set to 0.

TEND Flag (Transmission End Flag)

With no error signal from the receiving side, this bit is set to 1 when further data for transfer is ready to be transferred to the TDR register.

[Setting conditions]

- When SCR.TE bit = 0 (disabling serial transmission operations)
- When a specified period has elapsed after the latest transmission of one byte, the ERS flag is 0, and the TDR register is not updated

  The set timing is determined by register settings as listed below.

  When SMR.GM = 0 and SMR.BLK = 0, 12.5 etu after the start of transmission

  When SMR.GM = 0 and SMR.BLK = 1, 11.5 etu after the start of transmission

  When SMR.GM = 1 and SMR.BLK = 0, 11.0 etu after the start of transmission

  When SMR.GM = 1 and SMR.BLK = 1, 11.0 etu after the start of transmission

[Clearing condition]

- Writing further data for transmission to the TDR register

PER Flag (Parity Error Flag)

Indicates that a parity error has occurred during reception in asynchronous mode and the reception ends abnormally.
[Setting condition]

- When a parity error is detected during reception
  Although receive data when the parity error occurs is transferred to RDR, no RXI interrupt request occurs. Note that when the PER flag is being set to 1, the subsequent serial reception cannot be transferred to RDR.

[Clearing condition]
When a 0 is written to PER after reading PER = 1 (After writing a 0 to it, read the PER bit to check that it has actually been cleared to 0.)
Even when the RE bit in SCR is cleared to 0 (which indicates that serial reception is disabled), the PER flag is not affected and retains its previous value.

ERS Flag (Error Signal Status Flag)

[Setting condition]

- When a low error signal is sampled

[Clearing condition]

- When a 0 is written to ERS after reading ERS = 1

ORER Flag (Overrun Error Flag)

Indicates that an overrun error has occurred during reception and the reception ends abnormally.
[Setting condition]

- When the next data is received before receive data is read from RDR
  In RDR, the receive data prior to an overrun error occurrence is retained, but data received following the overrun error occurrence is lost. When the ORER flag is set to 1, subsequent serial reception cannot be performed.

[Clearing condition]

- When a 0 is written to ORER after reading ORER = 1 (After writing a 0 to it, read the ORER bit to check that it has actually been cleared to 0.)
  Even when the RE bit in SCR is cleared to 0, the ORER flag is not affected and retains its previous value.

RDRF Bit (Receive Data Full Flag)

- Indicates whether RDR has received data.

[Setting condition]

- When data has been received normally, and transferred from RSR to RDR

[Clearing condition]

- When data is transferred from RDR

TDRE Bit (Transmit Data Empty Flag)

- Indicates whether TDR has data to be transmitted.

[Setting condition]

- When data is transferred from TDR to TSR

[Clearing condition]

- When data is transferred to TDR

22.3.1.4 Bit Rate Register (BRR)

Address: SMCI0.BRR 0008 8241h, SMCI1.BRR 0008 8249h, SMCI2.BRR 0008 8251h

	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	1	1	1	1	1	1	1	1

BRR is an 8-bit register that adjusts the bit rate.
As the SCI performs baud rate generator control independently for each channel, different bit rates can be set for each channel.
The initial value of BRR is FFh.
BRR can be read from by the CPU at all times, but it can be written to only when the TE and RE bits in SCR are 0.
Table 21.15 shows the relationships between the N setting in BRR and bit rate B for smart card interface mode.
Table 28.15 shows sample N settings in BRR in smart card interface mode.
In smart card interface mode, the number of base clock cycles S in a 1-bit data transfer time can be selected. For details, see section 22.3.3.2, Receive Data Sampling Timing and Reception Margin.

Table 22.15 Relationships between N Setting in BRR and Bit Rate B

Mode	BRR Setting	Error
Smart card interface	$N = \frac{PCLK \times 10^6}{S \times 2^{2n+1} \times B} - 1$	$Error\ (\%) = \{ \frac{PCLK \times 10^6}{B \times S \times 2^{2n+1} \times (N+1)} - 1 \} \times 100$

B: Bit rate (bps)
N: BRR setting for baud rate generator ($0 \leq N \leq 255$)
PCLK: Operating frequency (MHz)
n and S: Determined by the SMR setting shown in the following table.

Table 22.16 BRR Settings for Various Bit Rates (Smart Card Interface Mode, n = 0, S = 372)

Bit Rate (bps)	Operating Frequency PCLK (MHz)											
	7.1424			10.00			10.7136			13.00		
	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
9600	0	0	0.00	0	1	0.00	0	1	25	0	1	8.99

Bit Rate (bps)	Operating Frequency PCLK (MHz)											
	14.2848			16.00			18.00			20.00		
	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
9600	0	0	0.00	0	1	12.04	0	2	15.99	0	2	6.66

Bit Rate (bps)	Operating Frequency PCLK (MHz)											
	25.00			30.00			33.00			50.00		
	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
9600	0	3	12.49	0	3	5.01	0	4	7.59	0	6	0.01

Table 22.17 Maximum Bit Rate for Each Operating Frequency (Smart Card Interface Mode, S = 372)

PCLK (MHz)	Maximum Bit Rate (bps)	n	N	PCLK (MHz)	Maximum Bit Rate (bps)	n	N
10.00	13441	0	0	20.00	26882	0	0
10.7136	14400	0	0	25.00	33602	0	0
13.00	17473	0	0	30.00	40323	0	0
16.00	21505	0	0	33.00	44355	0	0
18.00	24194	0	0	50.00	67205	0	0

22.3.2 Operation in Smart Card Interface Mode

The SCI supports the smart card (IC card) interface conforming to the ISO/IEC 7816-3 (Identification Card) standard, as an extended function of the SCI.
Smart card interface mode can be selected using the appropriate register.

22.3.2.1 Sample Connection

Figure 22.23 shows a sample connection between a smart card (IC card) and this LSI.
As in the figure, since this LSI communicates with an IC card using a single transmission line, interconnect the TXDn and RXDn pins and pull up the data transmission line to Vcc using a resistor.
Setting the TE and RE bits in SCR to 1 with an IC card disconnected enables closed transmission/reception allowing self diagnosis.
To supply an IC card with the clock pulses generated by the SCI, input the SCKn pin output to the CLK pin of an IC card.
The output port of the RX62T can be used to output a reset signal.

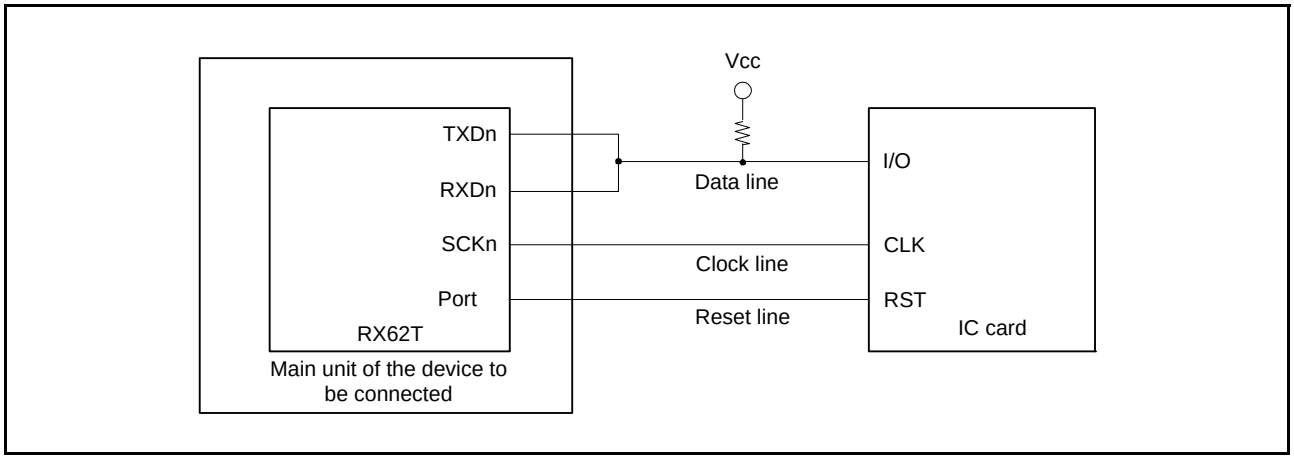


Figure 22.23 Sample Connection with a Smart Card (IC Card)

22.3.3 Data Format (Except in Block Transfer Mode)

Figure 22.24 shows the data transfer formats in smart card interface mode.
One frame consists of 8-bit data and a parity bit in asynchronous mode.
During transmission, at least 2 etu (elementary time unit: time required for transferring one bit) is secured as a guard time from the end of the parity bit until the start of the next frame.
If a parity error is detected during reception, a low-level error signal is output for 1 etu after 10.5 etu has passed from the start bit.
If an error signal is sampled during transmission, the same data is automatically re-transmitted after at least 2 etu.

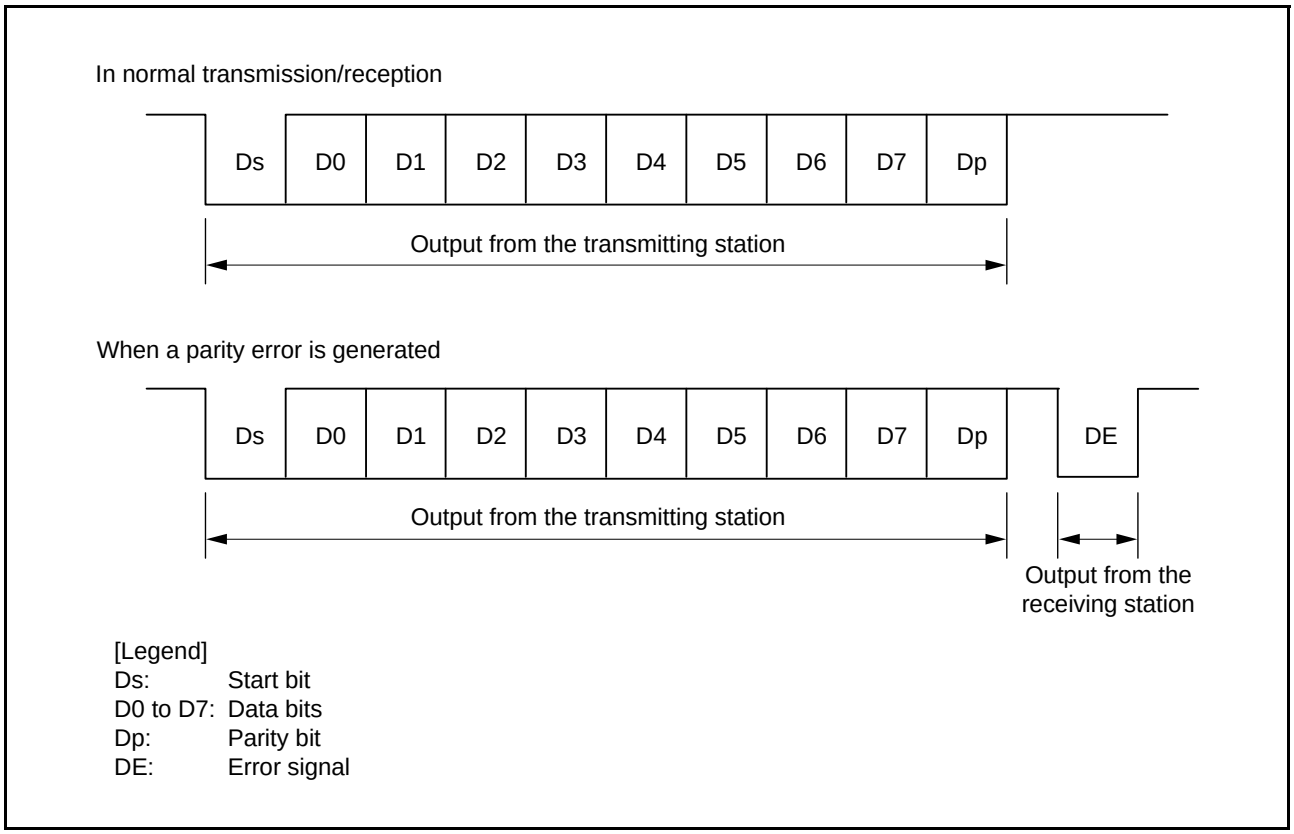


Figure 22.24 Data Formats in Smart Card Interface Mode

For communications with IC cards of the direct convention type and inverse convention type, follow the procedure below.

(1) Direct Convention Type

For the direct convention type, logic levels 1 and 0 correspond to states Z and A, respectively, and data is transferred with LSB-first as the start character, as shown in Figure 22.25. Therefore, data in the start character in the figure is 3Bh. When using the direct convention type, write 0 to both the SDIR and SINV bits in SCMR. Write 0 to the PM bit in SMR in order to use even parity, which is prescribed by the smart card standard.

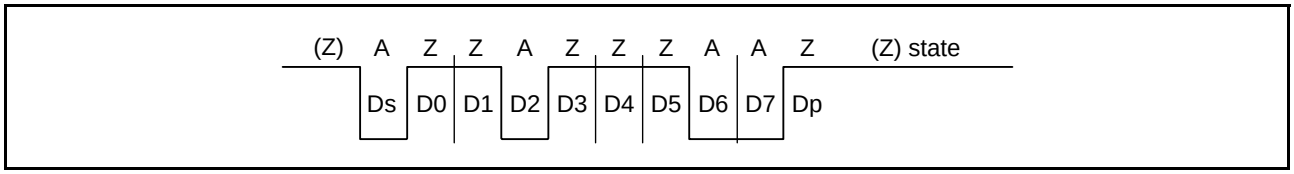


Figure 22.25 Direct Convention (SDIR in SCMR = 0, SINV in SCMR =0, PM in SMR = 0)

(2) Inverse Convention Type

For the inverse convention type, logic levels 1 and 0 correspond to states A and Z, respectively and data is transferred with MSB-first as the start character, as shown in Figure 22.26. Therefore, data in the start character in the figure is 3Fh. When using the inverse convention type, write 1 to both the SDIR and SINV bits in SCMR. The parity bit is logic level 0 to produce even parity, which is prescribed by the smart card standard, and corresponds to state Z. Since the SNIV bit of the RX62T only inverts data bits D7 to D0, write 1 to the PM bit in SMR to invert the parity bit for both transmission and reception.

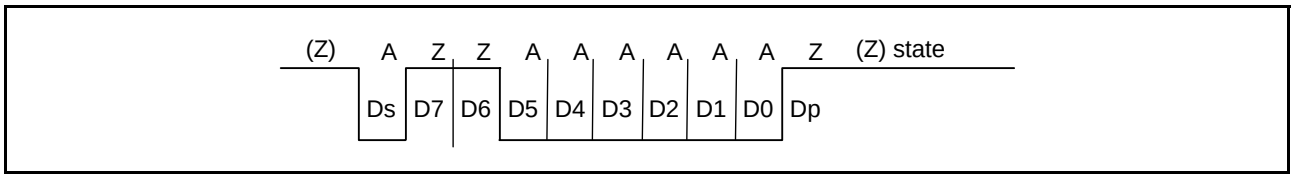


Figure 22.26 Inverse Convention (SDIR in SCMR = 1, SINV in SCMR =1, PM in SMR = 1)

22.3.3.1 Block Transfer Mode

Block transfer mode is different from normal smart card interface mode in the following respects.

- Even if a parity error is detected during reception, no error signal is output. Since the PER bit in SSR is set by error detection, clear the PER bit before receiving the parity bit of the next frame.
- During transmission, at least 1 etu is secured as a guard time from the end of the parity bit until the start of the next frame.
- Since the same data is not re-transmitted during transmission, the TEND flag in SSR is set 11.5 etu after transmission start.
- In block transfer mode, the ERS flag in SSR indicates the error signal status as in normal smart card interface mode, but the flag is always read as 0 because no error signal is transferred.

22.3.3.2 Receive Data Sampling Timing and Reception Margin

Only the internal clock generated by the on-chip baud rate generator can be used as a transfer clock in smart card interface mode.
In this mode, the SCI can operate on a base clock with a frequency of 32, 64, 372, 256, 93, 128, 186, or 512 times the bit rate according to the settings of the BCP2 bit in SCMR and the BCP[1:0] bits in SMR (the frequency is always 16 times the bit rate in normal asynchronous mode).
For data reception, the falling edge of the start bit is sampled with the base clock to perform internal synchronization. For data reception, the falling edge of the start bit is sampled with the base clock to perform internal synchronization. Receive data is sampled on the 16th, 32nd, 186th, 128th, 46th, 64th, 93rd, and 256th rising edges of the base clock so that it can be latched at the middle of each bit as shown in Figure 22.27. The reception margin here is determined by the following formula.

$$M = \left| (0.5 - \frac{1}{2N}) - (L - 0.5)\ F - \frac{\left| D - 0.5 \right|}{N}\ (1+F) \right| \times 100\ [\%]$$

M: Reception margin (%)
N: Ratio of bit rate to clock (N = 32, 64, 372, 256)
D: Duty cycle of clock (D = 0 to 1.0)
L: Frame length (L = 10)
F Absolute value of clock frequency deviation

Assuming values of F = 0, D = 0.5, and N = 372 in the above formula, the reception margin is determined by the formula below.

$M = \{0.5 - 1/(2 \times 372)\} \times 100\ (\%) = 49.866\%$

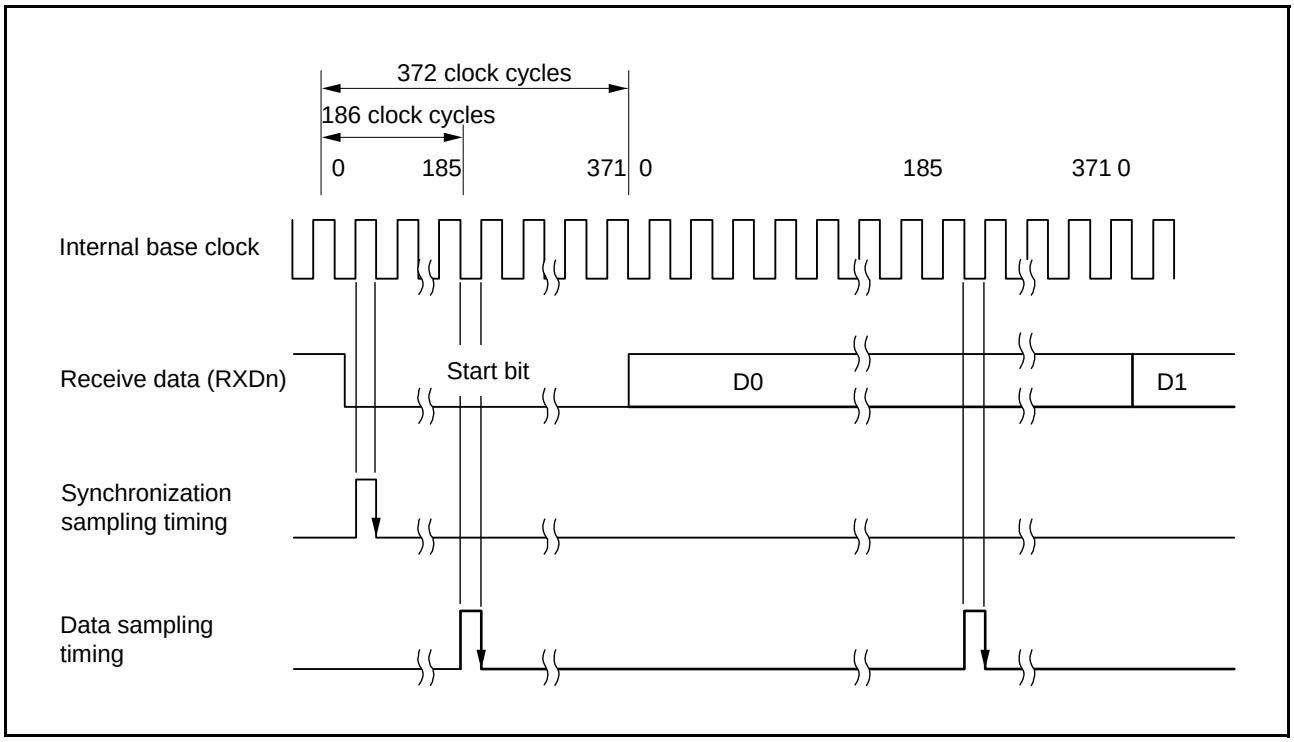


Figure 22.27 Receive Data Sampling Timing in Smart Card Interface Mode (When Clock Frequency is 372 Times the Bit Rate)

22.3.3.3 Initialization of the Smart Card Interface

Before transmitting and receiving data, initialize the SCI using the following procedure. Initialization is also necessary before switching from transmission to reception and vice versa.

1. Write the initial value "00h" to the SCR.
2. Set the Bj bit in ICR of PORTn (n = 1 to 9 and A to G, j = 0 to 7) of the corresponding pin to 1.
3. Set the error flags ORER, ERS, and PER in SSR to 0.
4. Set bits GM, BLK, OE, BCP[1:0], and CKS[1:0] in SMR and the BCP2 bit in SCMR appropriately. Also set the PE bit in SMR to 1.
5. Set bits SDIR, SINV, and SMIF in SCMR appropriately. Also set the Bj bit in DDR of PORTn corresponding to the TXDn pin to 0. Then the TXDn and RXDn pins are changed from port pins to SCI pins and placed in the high impedance state.
6. Set the value corresponding to the bit rate in BRR.
7. Set the CKE[1:0] bits in SCR appropriately, and set bits TIE, RIE, TE, RE, and TEIE in SCR to 0 at the same time. When the CKE0 bit is set to 1, the SCKn pin is allowed to output clock pulses.
8. Wait for at least a 1-bit interval, and then set the TIE, RIE, TE, and RE bits in SCR to 1. Setting the TE and RE bits to 1 simultaneously is prohibited except for self diagnosis.

To change reception mode to transmission mode, first check that reception has completed, and then initialize the SCI. At the end of initialization, set TE = 1 and RE = 0. Reception completion can be verified by reading the RXI request, ORER, or PER flag in SSR.
To change transmission mode to reception mode, first check that transmission has completed, and then initialize the SCI. At the end of initialization, set TE = 0 and RE = 1. Transmission completion can be verified by reading the TEND flag in SSR.

22.3.3.4 Serial Data Transmission (Except in Block Transfer Mode)

Serial data transmission in smart card interface mode (except in block transfer mode) is different from that in normal serial communications interface mode in that an error signal is sampled and data can be re-transmitted. Figure 22.28 shows the data re-transfer operation during transmission.

1. When an error signal from the receiving end is sampled after one-frame data has been transmitted, the ERS flag in SSR is set to 1. If the RIE bit in SCR is 1 at this time, an ERI interrupt request is generated. Clear the ERS flag to 0 before the next parity bit is sampled.
2. For a frame in which an error signal is received, the TEND flag in SSR is not set. Data is re-transferred from TDR to TSR allowing automatic data retransmission.
3. If no error signal is returned from the receiving end, the ERS flag is not set to 1.
4. In this case, the SCI judges that transmission of one-frame data (including retransfer) has been completed, and the TEND flag is set. If the TIE bit in SCR is 1 at this time, a TXI interrupt request is generated. Writing transmit data to TDR starts transmission of the next data.

Figure 22.30 shows a sample flowchart of serial transmission. All the processing steps are automatically performed using a TXI interrupt request to activate the DTC.
When the TEND flag in SSR is set to 1 in transmission, if the TIE bit in SCR is 1, a TXI interrupt request is generated. The DTC is activated by a TXI interrupt request if the TXI interrupt request is specified as a source of DTC activation beforehand, allowing transfer of transmit data. The TEND flag is automatically cleared to 0 when the DTC transfers the data.
If an error occurs, the SCI automatically re-transmits the same data. During this retransmission, the TEND flag is kept to 0 and the DTC is not activated. Therefore, the SCI and DTC automatically transmit the specified number of bytes, including retransmission in the case of error occurrence. However, since the ERS flag is not automatically cleared; set the RIE bit to 1 beforehand to enable an ERI interrupt request to be generated at error occurrence, and clear the ERS flag to 0.
When transmitting/receiving data using the DTC, be sure to make settings to enable the DTC before making SCI settings. For DTC settings, see section 14, Data Transfer Controller (DTC).

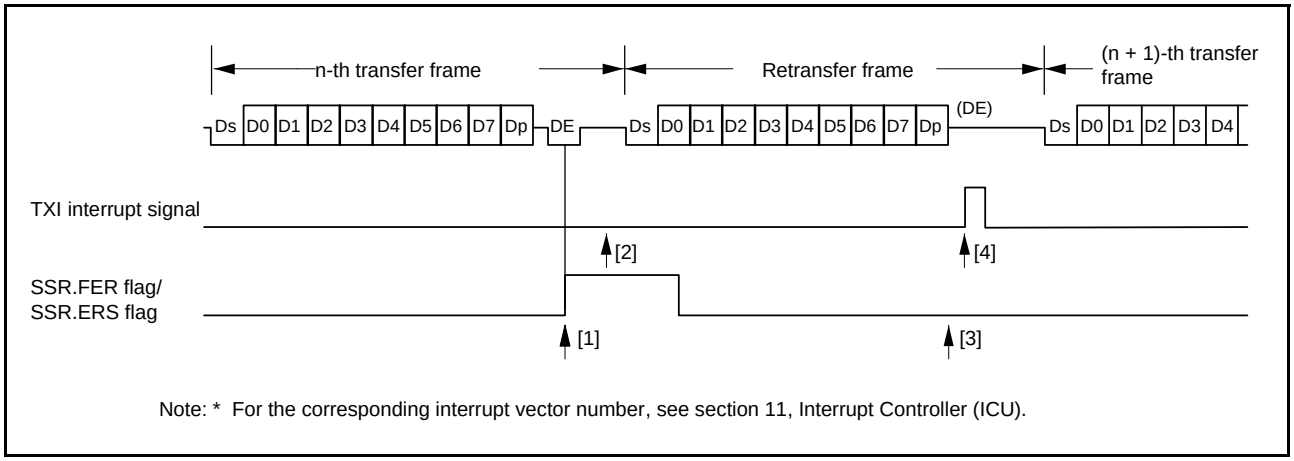


Figure 22.28 Data Retransfer Operation in SMCI Transmission Mode

Note that the SSR.TEND flag is set in different timings depending on the GM bit setting in SMR. Figure 22.29 shows the TEND flag generation timing.

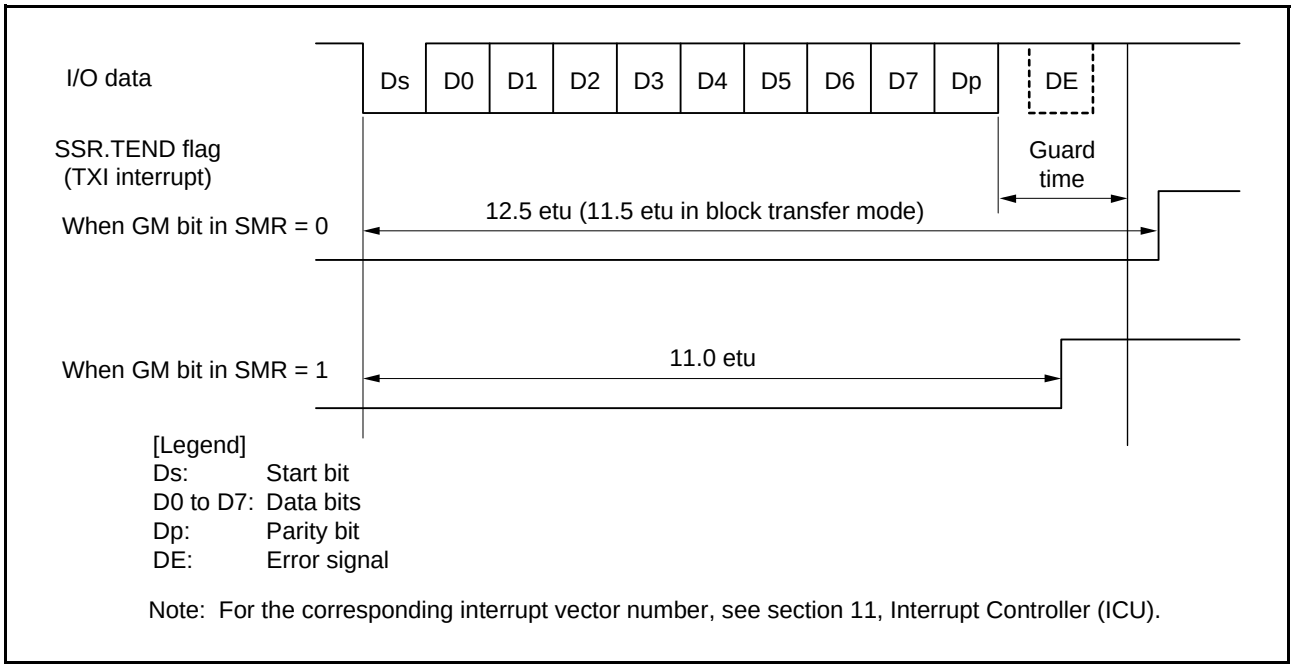


Figure 22.29 SSR.TEND Flag Generation Timing during Transmission

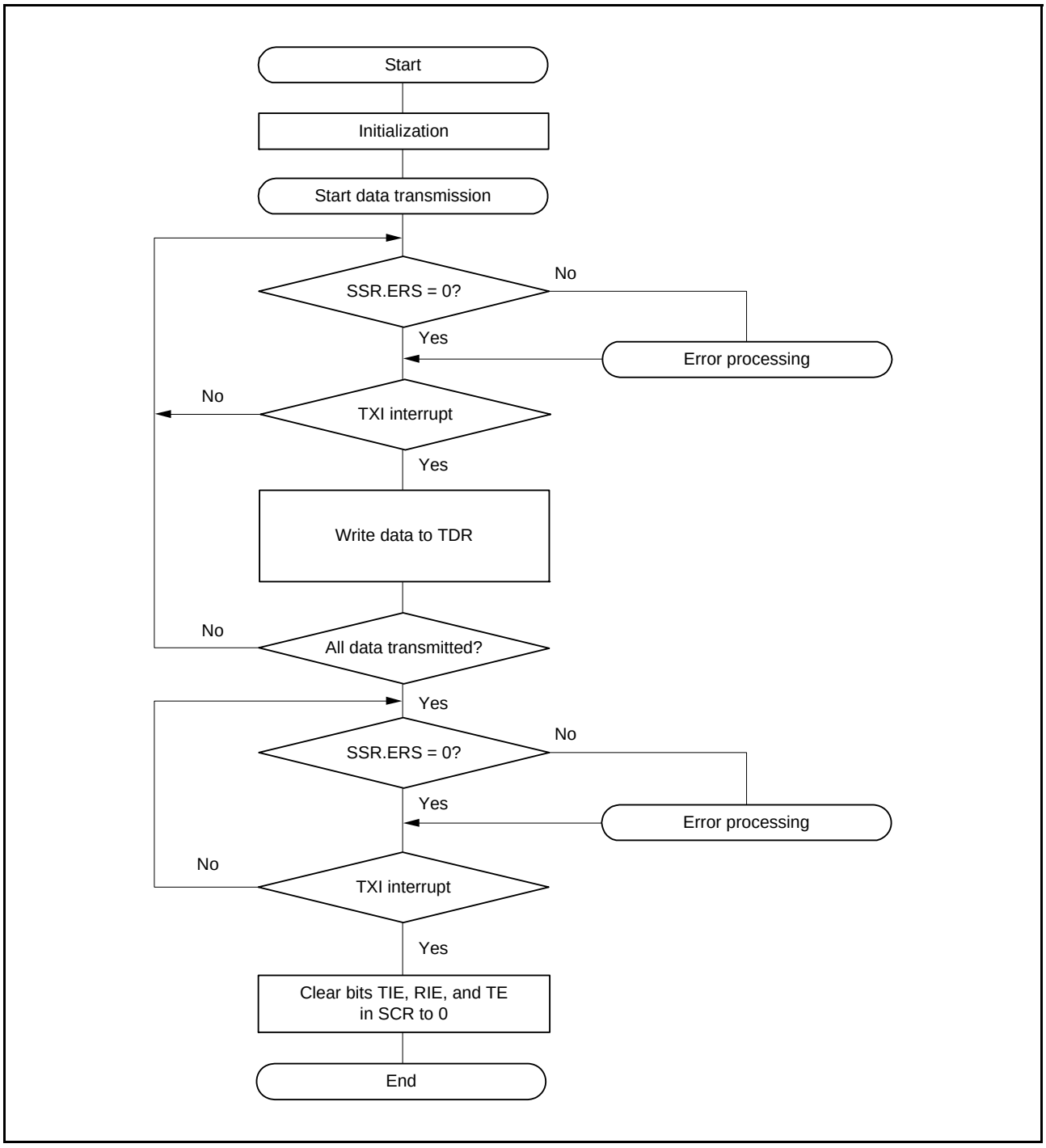


Figure 22.30 Sample Serial Transmission Flowchart

22.3.3.5 Serial Data Reception (Except in Block Transfer Mode)

Serial data reception in smart card interface mode is similar to that in serial communications interface mode. Figure 22.31 shows the data retransfer operation in reception mode.

1. If a parity error is detected in receive data, the PER flag in SSR is set to 1. When the RIE bit in SCR is 1 at this time, an ERI interrupt request is generated. Clear the PER flag to 0 before the next parity bit is sampled.
2. For a frame in which a parity error is detected, no RXI interrupt is generated.
3. When no parity error is detected, the PER flag in SSR is not set to 1.
4. In this case, data is determined to have been received successfully. When the RIE bit in SCR is 1, an RXI interrupt request is generated.

Figure 22.32 shows a sample flowchart for serial data reception. All the processing steps are automatically performed using an RXI interrupt request to activate the DTC.
In reception, setting the RIE bit to 1 allows an RXI interrupt request to be generated. The DTC is activated by an RXI interrupt request if the RXI interrupt request is specified as a source of DTC activation beforehand, allowing transfer of receive data.
If an error occurs during reception and either the ORER or PER flag in SSR is set to 1, a receive error interrupt (ERI) request is generated. Clear the error flag. If an error occurs, the DTC is not activated and receive data is skipped. Therefore, the number of bytes of receive data specified in the DTC is transferred.
Even if a parity error occurs and the PER flag is set to 1 during reception, receive data is transferred to RDR, thus allowing the data to be read.

Note: • For operations in block transfer mode, see section 22.2.2, Operation in Asynchronous Mode.

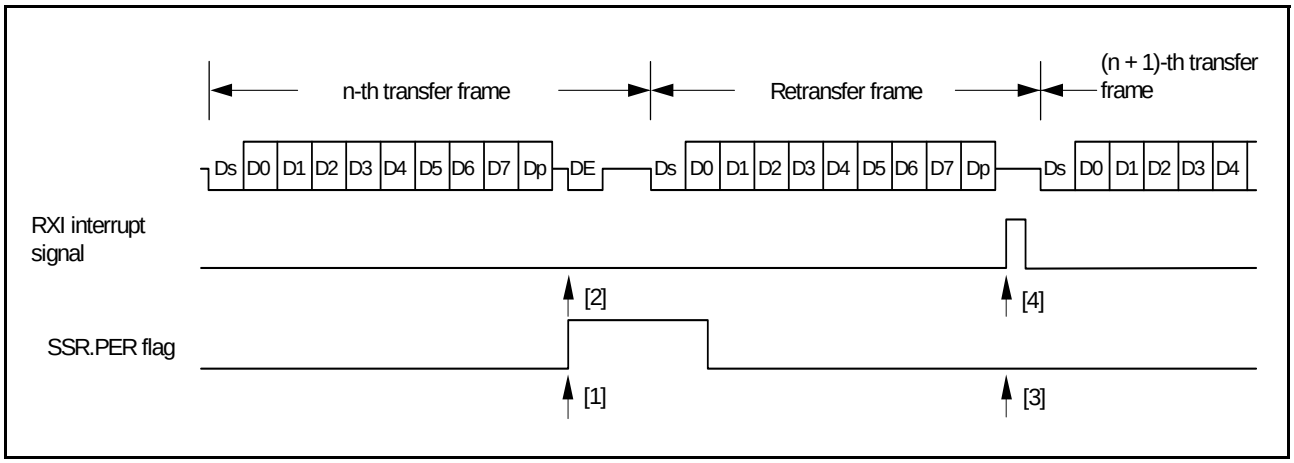


Figure 22.31 Data Retransfer Operation in SMCI Reception Mode

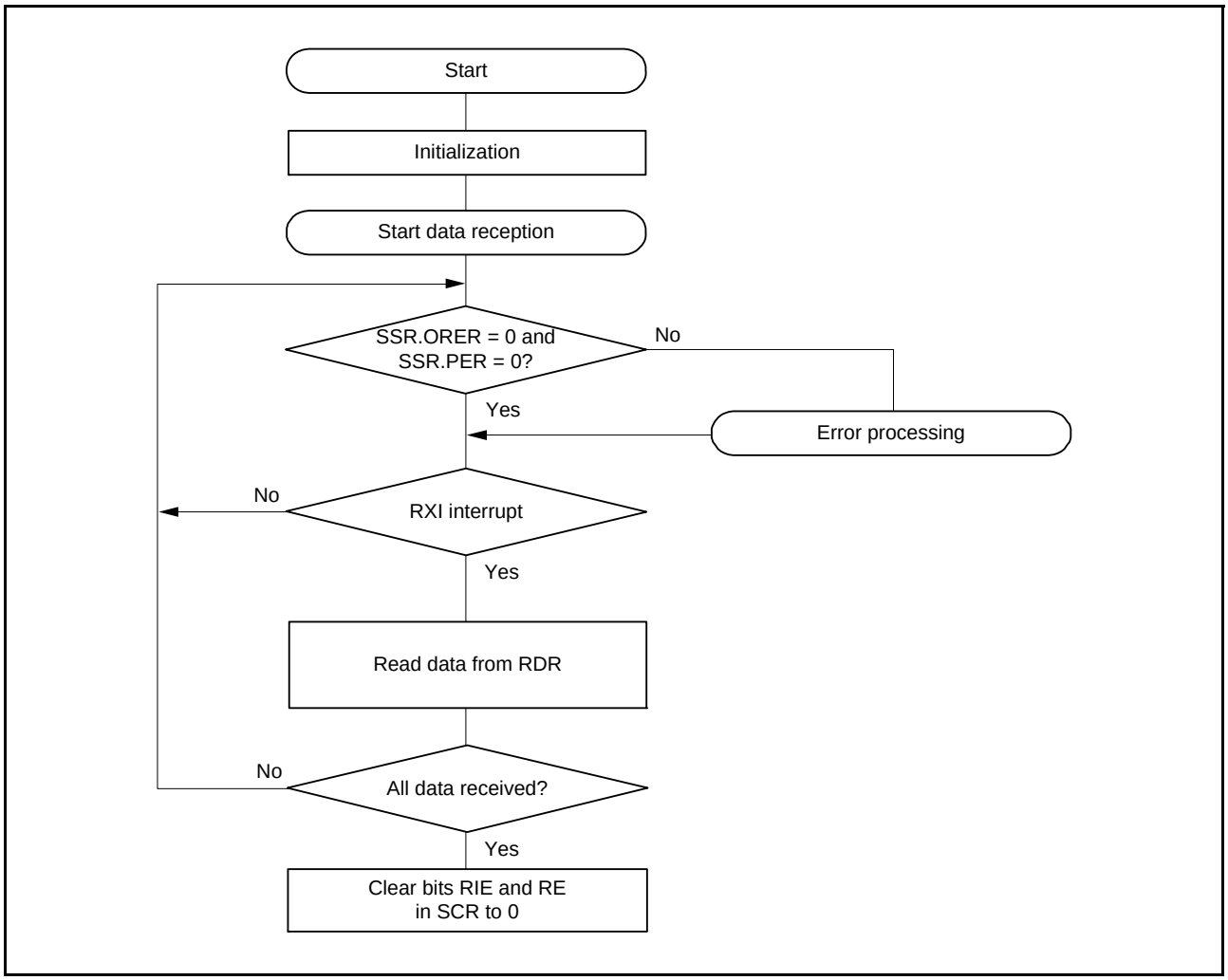


Figure 22.32 Sample Serial Reception Flowchart

22.3.3.6 Clock Output Control

Clock output can be stopped using the CKE[1:0] bits in SCR when the GM bit in SMR is 1. Specifically, the minimum width of a clock pulse can be specified.

Figure 22.33 shows an example of clock output stop timing when the CKE0 bit is controlled with GM = 1 and CKE1 = 0.

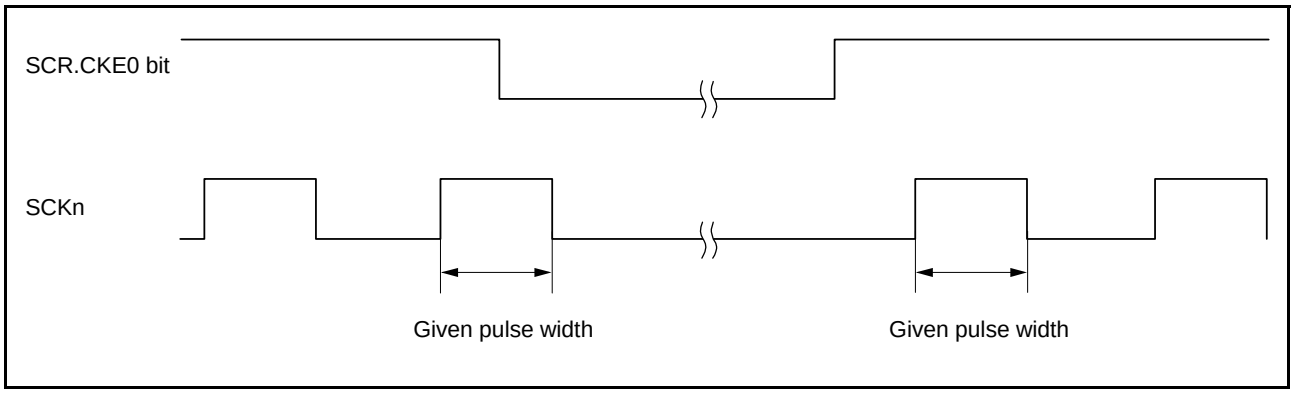


Figure 22.33 Clock Output Stop Timing

At power-on and transitions to/from software standby mode, use the following procedure to secure the appropriate clock duty cycle.

(1) At Power-On

To secure the appropriate clock duty cycle simultaneously with power-on, use the following procedure.

1. Initially, port input is enabled in the high-impedance state. To fix the potential level, use a pull-up or pull-down resistor.
2. Fix the SCKn pin to the specified output using the CKE1 bit in SCR.
3. Set SMR and SCMR to enable smart card interface mode. Set the CKE0 bit in SCR to 1 to start clock output.

(2) At Mode Switching

(a) At transition from smart card interface mode to software standby mode

1. Set the data register (DR of PORTi) and data direction register (DDR of PORTi) corresponding to the SCKn pin to the values for the output fixed state in software standby mode.
2. Write 0 to the TE and RE bits in SCR to stop transmission/reception.
   Simultaneously, set the CKE1 bit in SCR to the value for the output fixed state in software standby mode.
3. Write 0 to the CKE0 bit in SCR to stop the clock.
4. Wait for one cycle of the serial clock. In the mean time, the clock output stops with the low level retained after outputting the specified high width.
5. Make a transition to software standby mode.

(b) At transition from software standby mode to smart card interface mode

1. Cancel software standby mode.
2. Set the SCR.CKE0 bit to 1. The clock output with the specified clock frequency is then restarted.

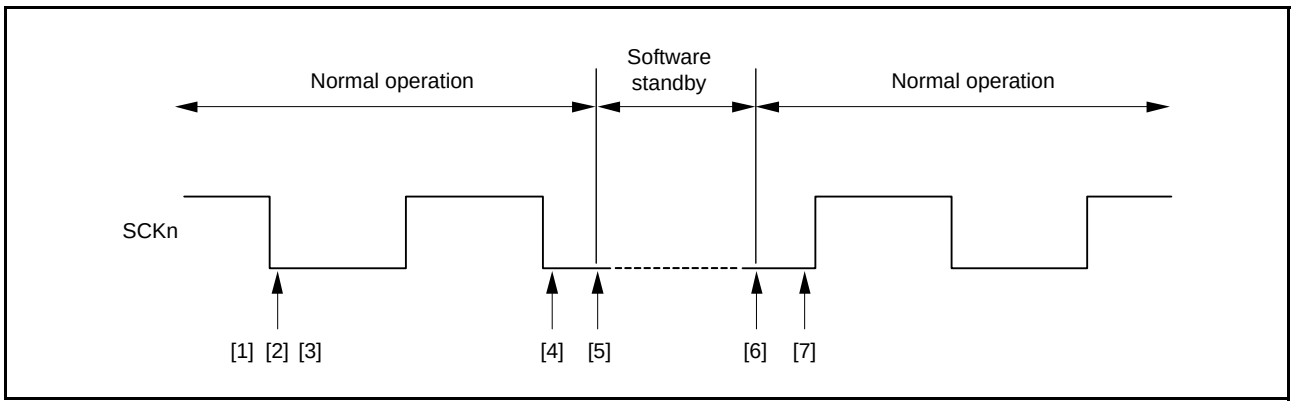


Figure 22.34 Clock Stop and Restart Procedure

22.4 Noise Cancellation

Figure 22.35 shows the structure of the noise cancellation circuit. This is used to eliminate noise on the RXD signal in asynchronous mode.When noise cancellation is enabled, the signal received on the RXD pin passes through this circuit before being handled within the SCI. The noise-cancelling function is made up of a three-stage latch circuit and a match detector.

When SEMR.ABCS = 0, the level received on RXD is passed through the three-stage latch circuit at 16 times the peripheral clock frequency, and if the levels in the three latches match, it is conveyed to the next stage. If the levels do not match, the level remains the same as the last time they did match.

That is, the noise-cancelling function recognizes the received signal if it has remained at the same level for at least three clock cycles but judges that it is noise, and thus rejects it, if it has not.

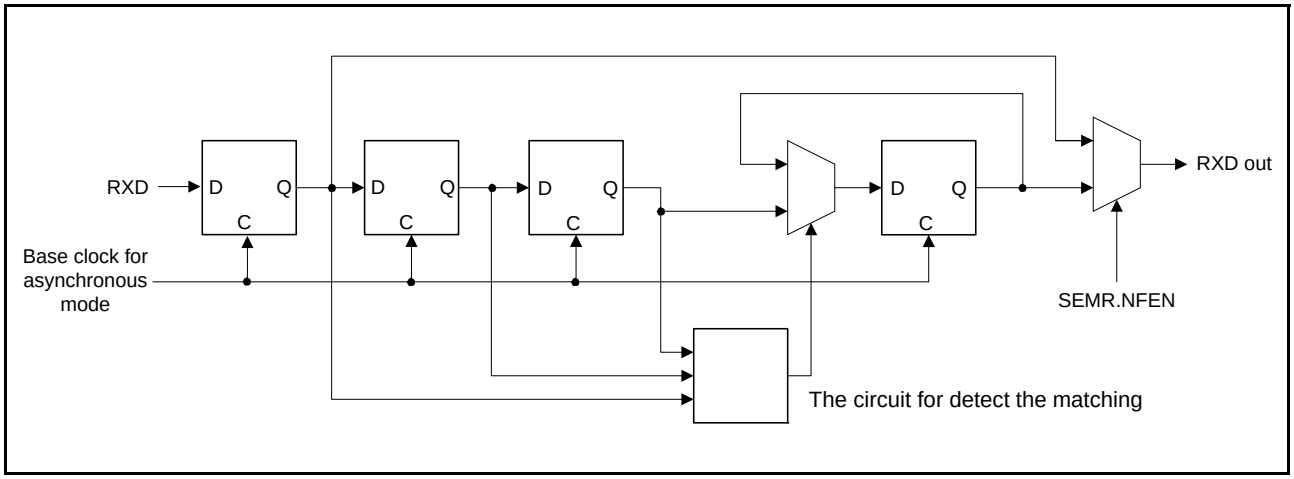


Figure 22.35 Configuration of the Noise-Cancelling Function

22.5 Interrupt Sources

22.5.1 Interrupts in Serial Communications Interface Mode

Table 22.18 lists interrupt sources in normal serial communications interface mode. A different interrupt vector is assigned to each interrupt source, and individual interrupt sources can be enabled or disabled with the enable bits in SCR.
Transfer of data from the transmit data register (TDR) to TSR while the TIE bit in SCR is 1 leads to the generation of a TXI interrupt request. Moreover, setting the TIE bit in SCR to 1 and then setting the TE bit to 1, or setting the TIE and TE bits in SCR to 1 simultaneously using one instruction, leads to the generation of a TXI interrupt request. A TXI interrupt request can activate the DTC for data transfer.
Setting of received data in RDR while the RIE bit in SCR is 1 leads to the generation of an RXI interrupt request. An RXI interrupt can activate the DTC for data transfer.
Setting the ORER, FER, or PER flag in SSR to 1 while the RIE bit in SCR is 1 leads to generation of an ERI interrupt request. Here, an RXI interrupt request is not generated.
If the TDR has not been updated by the time of transmission of the tail-end bit of data being transmitted, the TEND flag in SSR is set to 1 and, if the value of the TEIE bit in SCR is 1, a TEI interrupt request is generated. Writing of data to the TDR during TXI interrupt processing leads to clearing of the TEND flag in SSR and clearing of the TEI interrupt at its source. When clearing the TEND flag in SSR by writing transmit data to TDR, read the TEND flag in SSR to confirm that it is 0.
The TXI interrupt request is generated by setting the TIE bit in SCR to 1 and then setting the TE bit to 1 or by setting the TIE and TE bits in SCR to 1 simultaneously using one instruction. The TXI interrupt is not generated if the TE bit is set while the TIE bit is 0 or the TIE bit is set to 1 after the TE bit is set to 1. Therefore, to disable the TXI interrupt, perform the transmit end interrupt processing, and then start data transfer again, for example, in the final data transmission, the TXI interrupt should be enabled/disabled using the corresponding ICU.IERm.IENj bit.

Table 22.18 SCI Interrupt Sources

Name	Interrupt Source	Interrupt Flag	DTC Activation	Priority
ERI	Receive error	ORER, FER, or PER	Not possible	High
RXI	Receive data full	—	Possible	↑
TXI	Transmit data empty	—	Possible	
TEI	Transmit end	TEND	Not possible	Low

22.5.2 Interrupts in Smart Card Interface Mode

Table 22.19 lists interrupt sources in smart card interface mode. A transmit end interrupt (TEI) request cannot be used in this mode.

Table 22.19 SCI Interrupt Sources

Name	Interrupt Source	Interrupt Flag	DTC Activation	Priority
ERI	Receive error or error signal detection	ORER, PER, or ERS	Not possible	High
RXI	Receive data full	—	Possible	↑
TXI	Transmit data empty	TEND	Possible	Low

Data transmission/reception using the DTC is also possible in smart card interface mode, similar to in the normal SCI mode. In transmission, when the TEND flag in SSR is set to 1, a TXI interrupt request is generated. This TXI interrupt request activates the DTC allowing transfer of transmit data if the TXI request is specified beforehand as a source of DTC activation. The TEND flag is automatically cleared to 0 when the DTC transfers the data.

If an error occurs, the SCI automatically re-transmits the same data. During the retransmission, the TEND flag is kept to 0 and the DTC is not activated. Therefore, the SCI and DTC automatically transmit the specified number of bytes, including retransmission in the case of error occurrence. However, the ERS flag in SSR is not automatically cleared to 0 at error occurrence. Therefore, the ERS flag must be cleared by previously setting the RIE bit in SCR to 1 to enable an ERI interrupt request to be generated at error occurrence.

When transmitting/receiving data using the DTC, be sure to make settings to enable the DTC before making SCI settings. For DTC settings, see section 14, Data Transfer Controller (DTC).

In reception, an RXI interrupt request is generated when receive data is set to RDR. This RXI interrupt request activates the DTC allowing transfer of receive data if the RXI request is specified beforehand as a source of DTC activation. If an error occurs, the error flag is set. Therefore, the DTC is not activated and an ERI interrupt request is issued to the CPU instead; the error flag must be cleared.

22.6 Usage Notes

22.6.1 Setting the Module Stop Function

Operation of the SCI can be disabled or enabled using the module stop control register B (MSTPCRB). The initial setting is for operation of the SCI to be halted. Register access is enabled by clearing the module stop state. For details, see section 9, Low Power Consumption.

22.6.2 Break Detection and Processing

When a framing error is detected, a break can be detected by reading the RXDn pin value directly. In a break, the input from the RXDn pin becomes all 0s, and so the FER flag in SSR is set to 1 (framing error), and the PER flag in SSR may also be set to 1 (parity error). The SCI continues the receive operation even after a break is received. Therefore, note that even if the FER flag is cleared to 0 (no framing error), it will be set to 1 again.

22.6.3 Mark State and Break Detection

When the TE bit in SCR is 0 (serial transmission disabled), the TXDn pin is used as an I/O port whose direction (input or output) and level are determined by the Bj bit in DR of PORTi and Bj bit in DDR of PORTi. This can be used to set the TXDn pin to mark state or send a break during serial data transmission. To maintain the communications line in mark state (the state of 1) until the TE bit is set to 1 (to enable serial transmission), set both Bj bit in DR of PORTi and Bj bit in DDR of PORTi to 1. Since the TE bit is cleared to 0 at this time, the TXDn pin becomes an I/O port, and 1 is output from the TXDn pin. To send a break during serial data transmission, first set Bj bit in DDR of PORTi = 1 and Bj bit in DR of PORTi = 0, and then clear the TE bit to 0. When the TE bit is cleared to 0, the transmitter is initialized regardless of the current transmission state, the TXDn pin becomes an I/O port, and a 0 is output from the TXDn pin.

22.6.4 Receive Error Flags and Transmit Operations (Clock Synchronous Mode Only)

Transmission cannot be started when a receive error flag (ORER, FER, or RER) in SSR is set to 1, even if data is written to TDR. Be sure to clear the receive error flags to 0 before starting transmission. Note also that the receive error flags cannot be cleared to 0 even if the RE bit in SCR is cleared to 0 (serial reception disabled).

22.6.5 Writing Data to TDR

Data can always be written to TDR. However, if new data is written to TDR when transmit data is remaining in TDR, the previous data in TDR is lost because it has not been transferred to TSR yet. Be sure to write transmit data to TDR in the TXI interrupt request processing routine.

22.6.6 Restrictions on Clock Synchronous Transmission

When the external clock source is used as a synchronization clock, update TDR by the DTC and wait for at least five clock cycles of PCLK before allowing the transmit clock to be input. If the transmit clock is input within four clock cycles after TDR is updated, the SCI may malfunction.

22.6.7 Restrictions on Using DTC

When using the DTC to read RDR, be sure to set the receive end interrupt (RXI) as the activation source of the relevant SCI.

22.6.8 SCI Operations during Low Power Consumption State

(1) Transmission

Before specifying the module stop state or making a transition to software standby mode, stop the transmit operations (TIE = TE = TEIE = 0 in SCR). TSR, TDR, and SSR are reset. Setting the TE bit to 0 modifies the TSR register and the SSR.TEND flag to 0. The states of the output pins in the module stop state or in software standby mode depend on the port settings, and the output pins are held high after cancellation. If the transition is made during data transmission, transmission will be suspended.

To transmit data in the same transmission mode after cancellation of the low power consumption state, set the TE bit to 1, read SSR, and write data to TDR sequentially to start data transmission. To transmit data with a different transmission mode, initialize the SCI first.

Figure 22.36 shows a sample flowchart for transition to software standby mode during transmission. Figure 22.37 and 21.38 show the port pin states during transition to software standby mode.

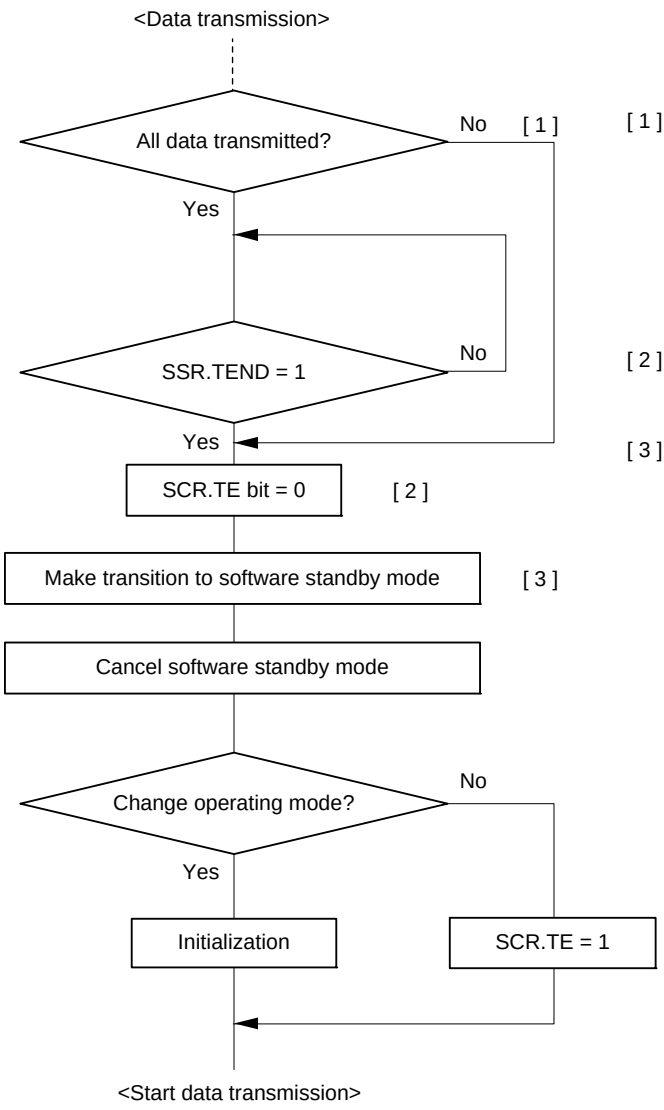
Before specifying the module stop state or making a transition to software standby mode from the transmission mode using DTC transfer, stop the transmit operations. To start transmission after cancellation using the DTC, set the TE bit to 1. The TXI interrupt flag is set to 1 and transmission starts using the DTC.

(2) Reception

Before specifying the module stop state or making a transition to software standby mode, stop the receive operations (RE in SCR = 0). If transition is made during data reception, the data being received will be invalid.

To receive data in the same reception mode after cancellation of the low power consumption state, set the RE bit to 1, and then start reception. To receive data in a different reception mode, initialize the SCI first.

Figure 22.39 shows a sample flowchart for mode transition during reception.



[1] Data being transmitted is lost halfway. Data can be normally transmitted from the CPU by setting the TE bit in SCR to 1, reading SSR, and writing data to TDR after canceling software standby mode. However, if the DTC has been activated, the data remaining in the DTC will be transmitted when both the TE and TIE bits in SCR are set to 1.

[2] Clear the TIE and TEIE bits in SCR to 0 when they are 1.

[3] Setting for the module stop state is included.

Figure 22.36 Example of Flowchart for Transition to Software Standby Mode during Transmission

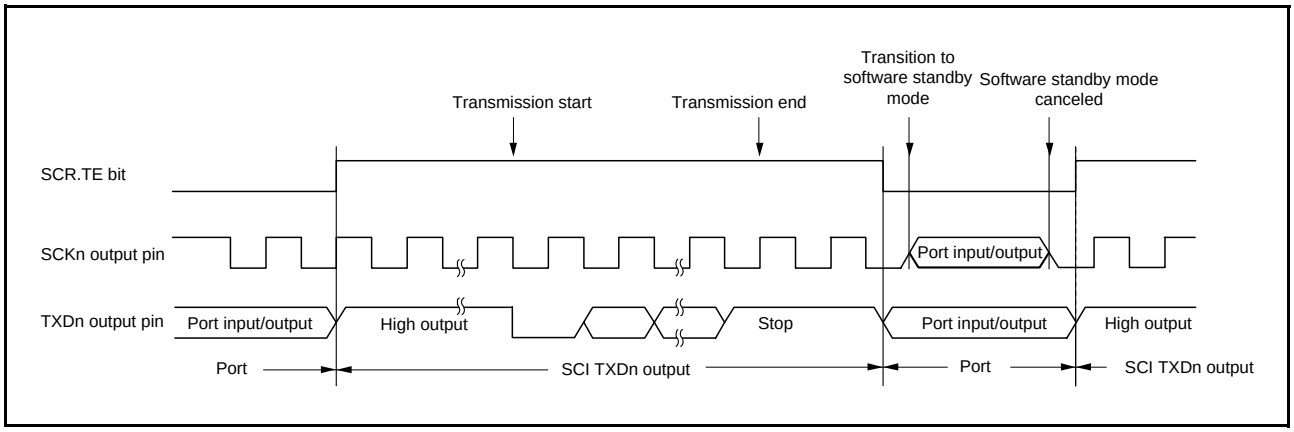


Figure 22.37 Port Pin States during Transition to Software Standby Mode (Internal Clock, Asynchronous Transmission)

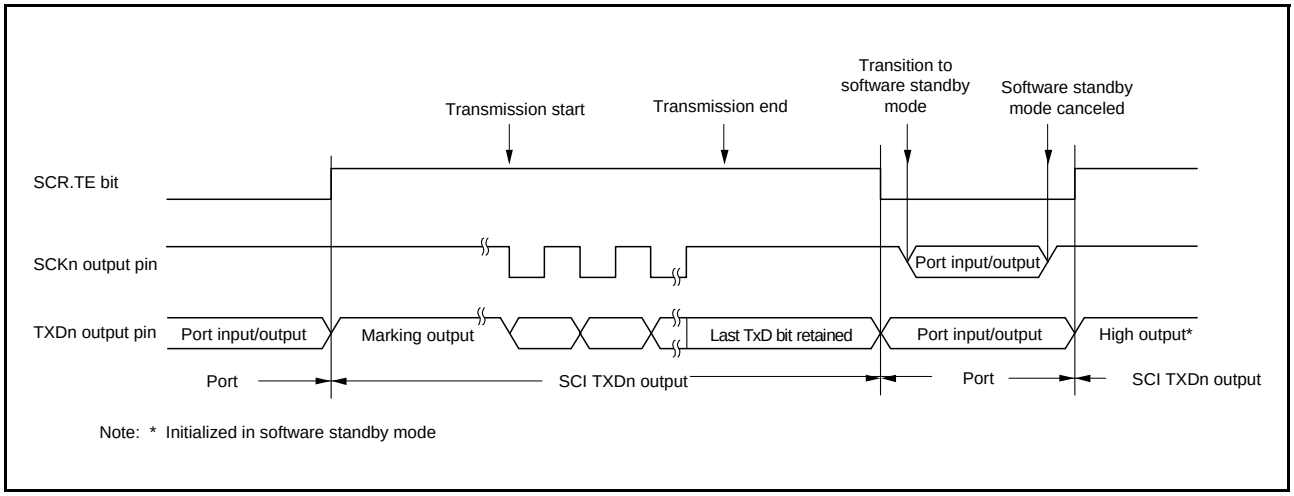


Figure 22.38 Port Pin States during Transition to Software Standby Mode (Internal Clock, Clock Synchronous Transmission)

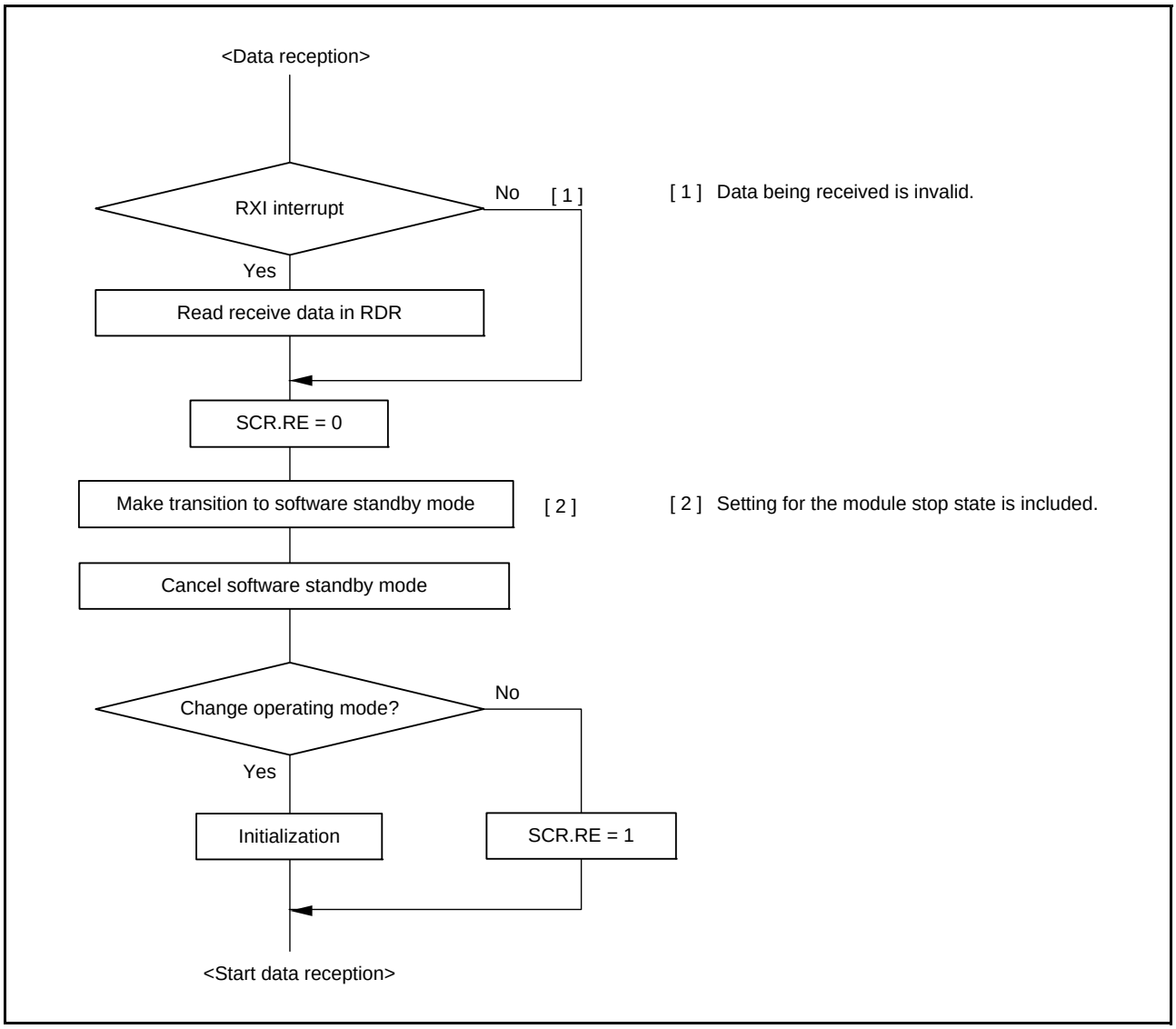


Figure 22.39 Example of Flowchart for Transition to Software Standby Mode during Reception

22.6.9 External Clock Input in Clock Synchronous Mode

In clock synchronous mode, the external clock SCKn must be input as follows:
High-pulse period, low-pulse period = 2 PCLK or more, period = 6 PCLK or more

23. CRC Calculator (CRC)

The CRC (Cyclic Redundancy Check) calculator generates CRC codes of data blocks.

23.1 Overview

Table 23.1 lists the specifications of the CRC calculator, and Figure 23.1 shows a block diagram of the CRC calculator.

Table 23.1 Specifications of CRC

Item	Description
Data for CRC calculation*1	CRC code generated for any desired data in 8n-bit units (where n is a whole number)
Data block size	8 bits
CRC processor unit	Operation executed on eight bits in parallel
CRC generating polynomial	One of three generating polynomials selectable • 8-bit CRC $X^8 + X^2 + X + 1$ • 16-bit CRC $X^{16} + X^{15} + X^2 + 1$ $X^{16} + X^{12} + X^5 + 1$
CRC calculation switching	CRC code generation for LSB-first or MSB-first communication selectable
Power-down function	Module stop state can be set

Note 1. The circuit does not have functionality to divide data for calculation into a data-block size. Write data in 8-bit units.

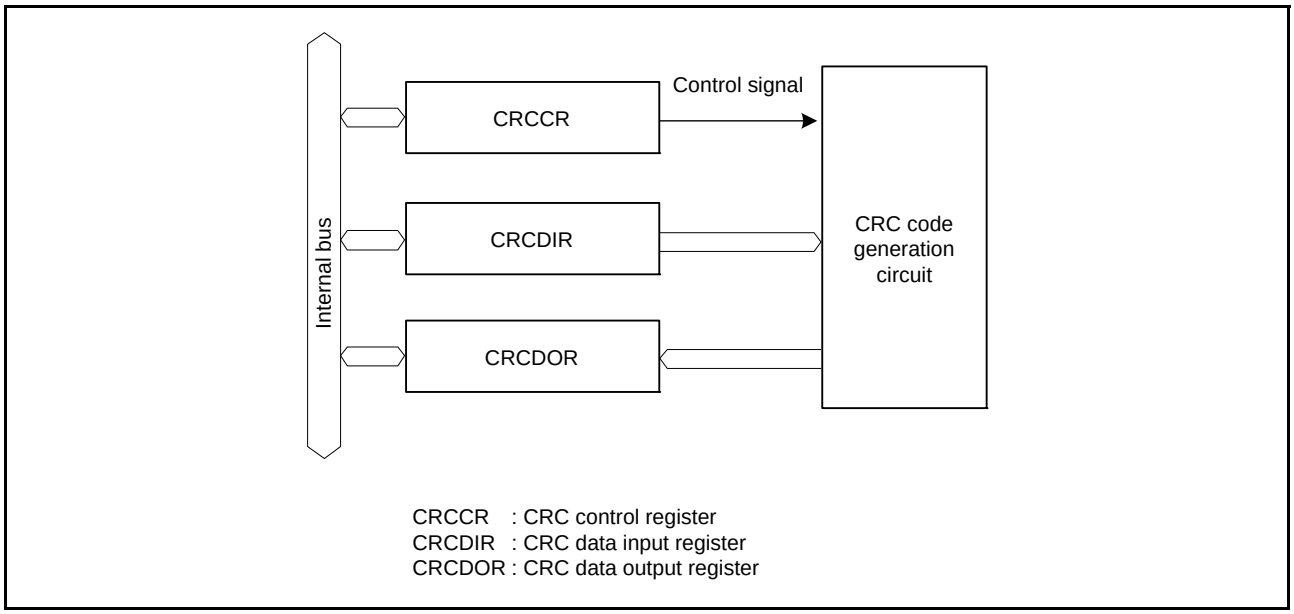


Figure 23.1 Block Diagram of CRC Calculator

23.2 Register Descriptions

Table 23.2 lists the registers of the CRC calculator.

Table 23.2 Registers of CRC Calculator

Register Name	Symbol	Value after Reset	Address	Access Size
CRC control register	CRCCR	00h	0008 8280h	8
CRC data input register	CRCDIR	00h	0008 8281h	8
CRC data output register	CRCDOR	0000h	0008 8282h	16

23.2.1 CRC Control Register (CRCCR)

Address: 0008 8280h

	b7	b6	b5	b4	b3	b2	b1	b0
	DORCLR	—	—	—	—	LMS	GPS[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1, b0	GPS[1:0]	CRC Generating Polynomial Switching	b1 b0 0 0: No calculation is executed.*1 0 1: $X^8 + X^2 + X + 1$ 1 0: $X^{16} + X^{15} + X^2 + 1$ 1 1: $X^{16} + X^{12} + X^5 + 1$	R/W
b2	LMS	CRC Calculation Switching	0: Performs CRC operation for LSB-first communication. The lower-order byte (bits 7 to 0) is the first to be transmitted when the contents of the CRCDOR (CRC code) are divided into bytes. 1: Performs CRC operation for MSB-first communication. The higher-order byte (bits 15 to 8) is first to be transmitted when the contents of the CRCDOR (CRC code) are divided into bytes.	R/W
b6 to b3	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7	DORCLR	CRCDOR Register Clear	0: No effect on the operation 1: Clear the CRCDOR register This bit is always read as 0.	R/W

Note 1. The CRC data output register (CRCDOR) is always 0000h.

CRCCR initializes the CRC calculator, switches the operation mode, and selects the generating polynomial.

GPS[1:0] Bits (CRC Generating Polynomial Switching)

These bits select the CRC code generating polynomial.

LMS Bit (CRC Calculation Switching)

Selects LSB-first or MSB-first communication for the CRC code generation.

DORCLR Bit (CRCDOR Register Clear)

Write 1 to this bit so that the CRCDOR register is cleared to 0000h.
This bit is always read as 0.

23.2.2 CRC Data Input Register (CRCDIR)

Address: 0008 8281h

	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	0	0	0	0	0	0	0	0

CRCDIR is an 8-bit readable/writable register, to which the bytes to be CRC-operated are written.

23.2.3 CRC Data Output Register (CRCDOR)

Address: 0008 8282h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

CRCDOR is a 16-bit readable/writable register that contains the result of CRC calculation.
In general, the value will be 0 if there is no CRC error when the calculated CRC code matches the CRC code that continues on, for verification, from the transferred data.
When eight-bit CRC codes (from the polynomial $X^8 + X^2 + X + 1$) are in use, the valid CRC code is obtained from the lower-order byte (b7 to b0). The higher-order byte (b15 to b8) is not updated.

23.3 Operation

The CRC calculator is capable of generating LSB- or MSB-first CRC codes for transfer.
Examples of usage for CCR code-generation from the data F0h with the CRCCR.GPS[1:0] bits set to 11b to select 16-bit CCR codes (from the polynomial $X^{16} + X^{12} + X^5 + 1$) are given below.
When eight-bit CRC codes (from the polynomial $X^8 + X^2 + X + 1$) are in use, the valid CRC code is obtained from the lower-order byte (b7 to b0).

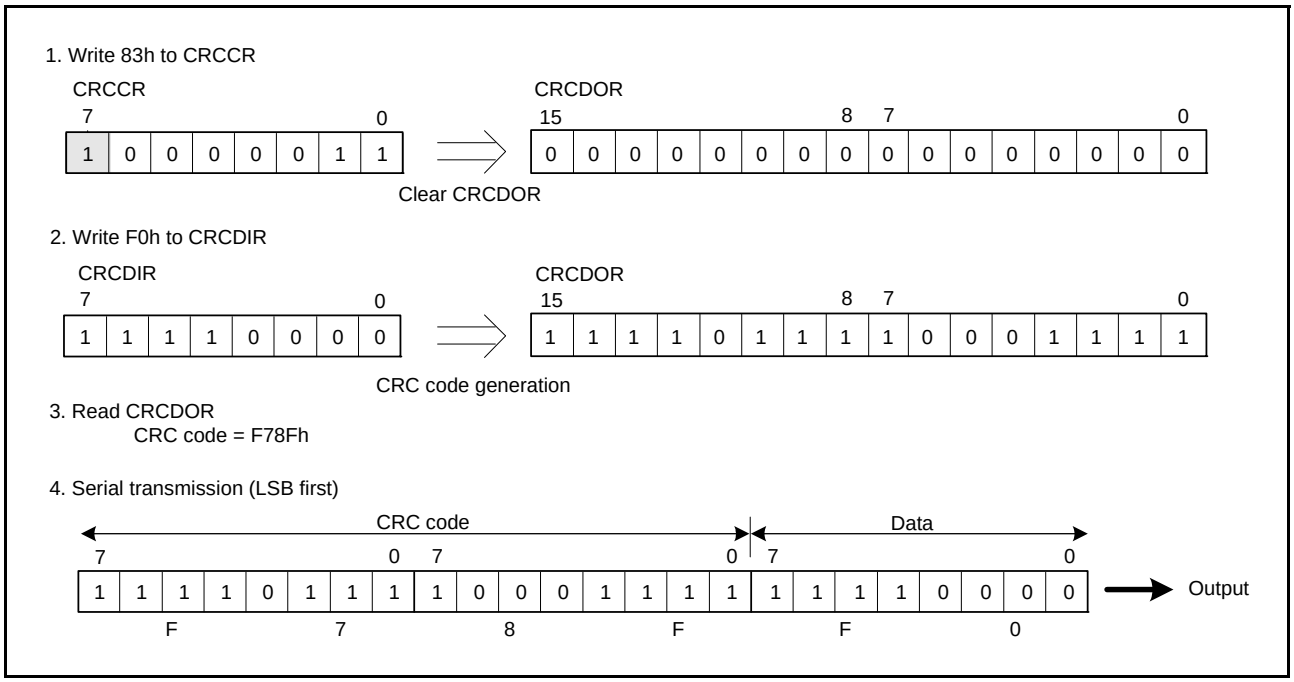


Figure 23.2 LSB-First Data Transmission

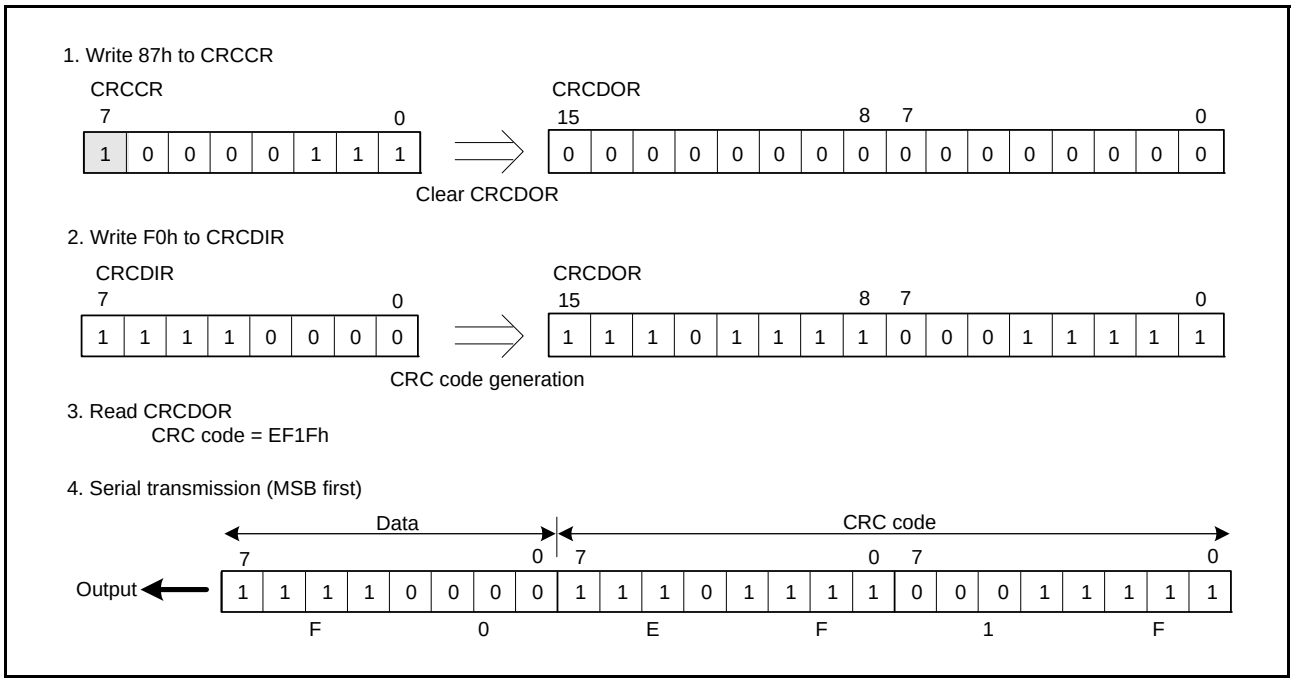


Figure 23.3 MSB-First Data Transmission

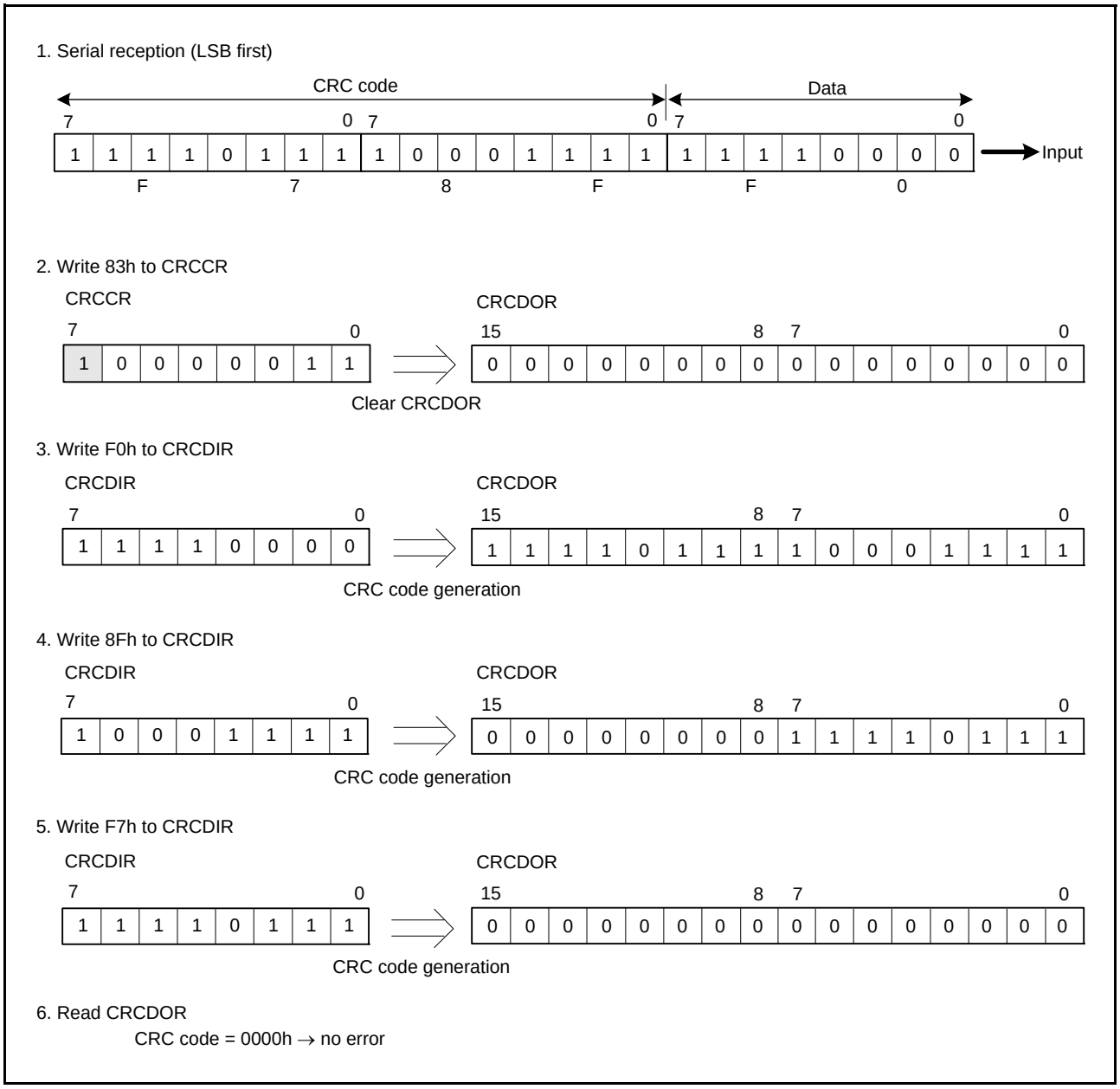


Figure 23.4 LSB-First Data Reception

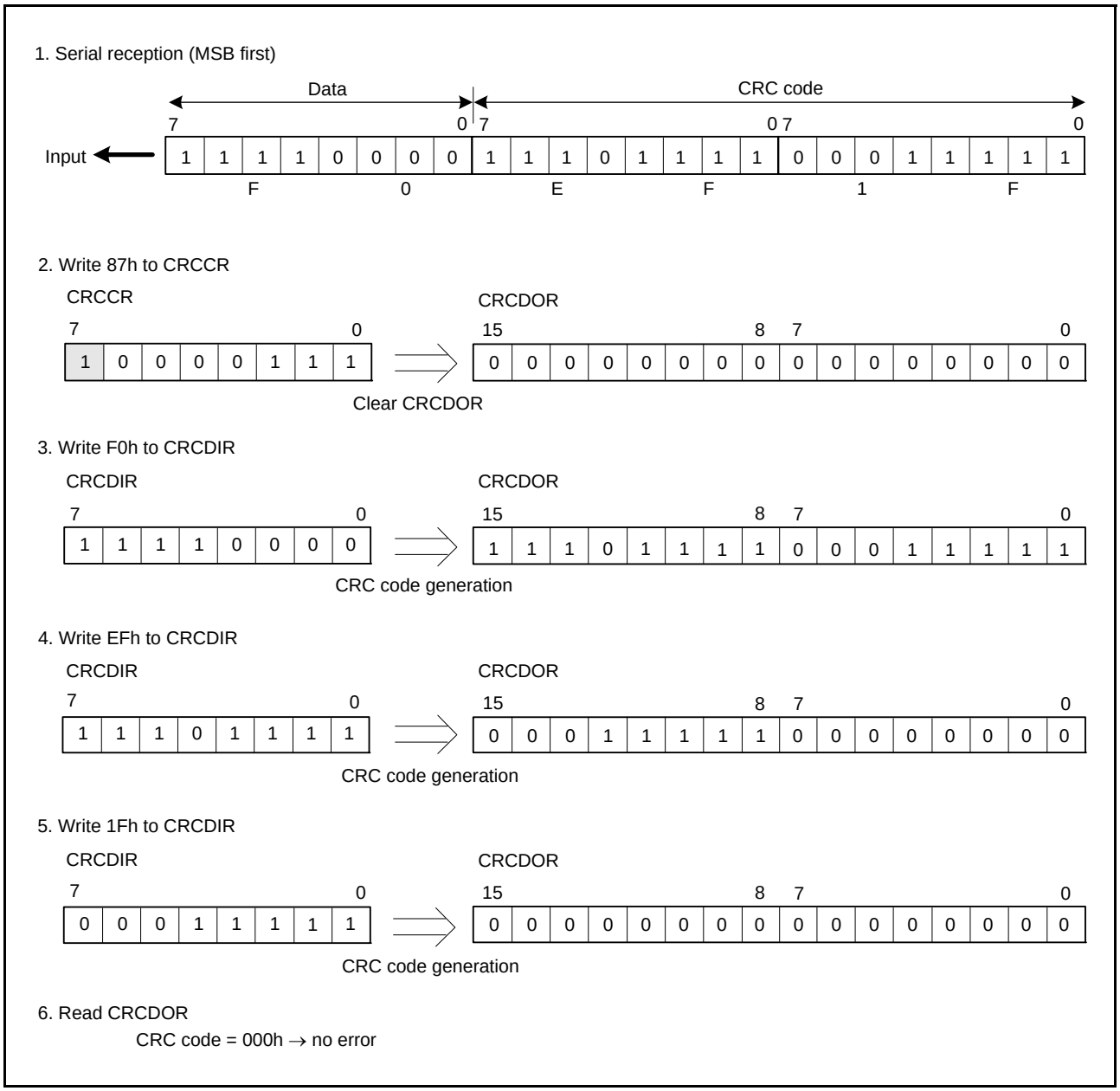


Figure 23.5 MSB-First Data Reception

23.4 Usage Notes

23.4.1 Module Stop Function Setting

Operation of the CRC calculator can be disabled or enabled using the module stop control register B (MSTPCRB). The initial setting is for operation of the CRC calculator to be halted. Register access is enabled by clearing the module stop state. For details, see section 9, Low Power Consumption.

23.5 Note on Transmission

Note that the sequence of transmission for the CRC code differs according to whether transmission is LSB-first or MSB-first.

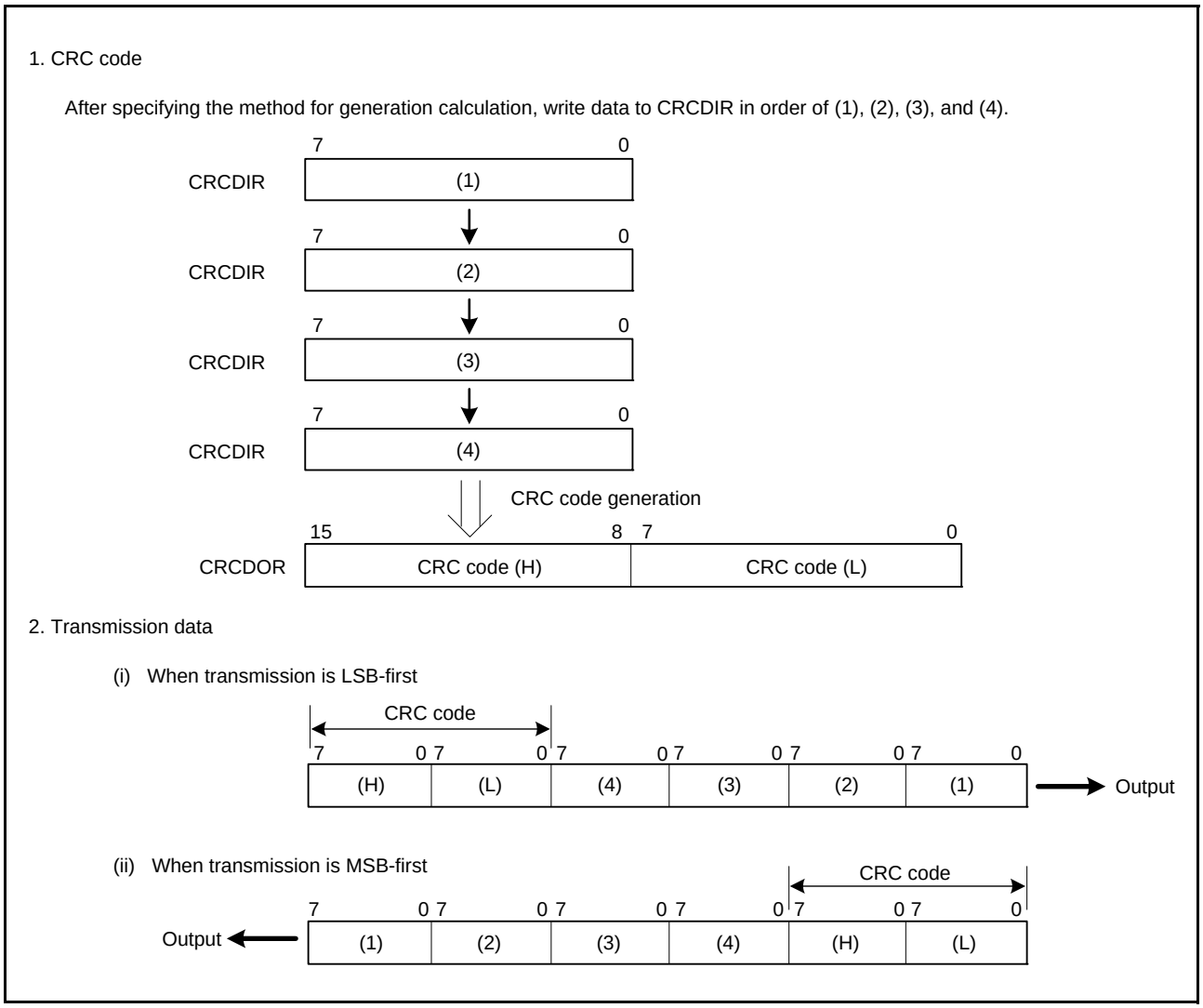


Figure 23.6 LSB-First and MSB-First Data Transmission

24. I2C Bus Interface (RIIC)

The RX62T Group has one I2C bus interface (RIIC module).
The RIIC module conforms with and provides a subset of the NXP I2C bus (inter-IC bus) interface functions.

24.1 Overview

Table 24.1 lists the specifications of the RIIC, Figure 24.1 shows a block diagram of the RIIC, and Figure 24.2 shows an example of I/O pin connections to external circuits (I2C bus configuration example). Table 24.2 shows the input/output pins of the RIIC.

Table 24.1 RIIC Specifications

Item	Specifications
Communications format	• I2C bus format or SMBus format • Master mode or slave mode selectable • Automatic securing of the various set-up times, hold times, and bus-free times for the transfer rate
Transfer rate	Up to 400k bps
SCL clock	• For master operation, the duty cycle of the SCL clock is selectable in the range from 4% to 96%.
Issuing and detecting conditions	Start, restart, and stop conditions are automatically generated. Start conditions (including restart conditions) and stop conditions are detectable.
Slave address	• Up to three slave-address settings can be made. • Seven- and ten-bit address formats are supported (along with the use of both at once). • General call addresses, device ID addresses, and SMBus host addresses are detectable.
Acknowledgement	• For transmission, the acknowledge bit is automatically loaded. Transfer of the next data for transmission can be automatically suspended on detection of a not-acknowledge bit. • For reception, the acknowledge bit is automatically transmitted. If a wait between the eighth and ninth clock cycles has been selected, software control of the value in the acknowledge field in response to the received value is possible (i.e. the return of ACK or NACK is selectable).
Wait function	• In reception, the following periods of waiting can be obtained by holding the clock signal (SCL) at the low level: waiting between the eighth and ninth clock cycles (timing of the received data full interrupt can be selected for this); and waiting between the ninth clock cycle and the first clock cycle of the next transfer (WAIT function)
SDA output delay function	• Timing of the output of transmitted data, including the not-acknowledge bit, can be delayed.
Arbitration	• For multi-master operation Operation to synchronize the SCL (clock) signal in cases of conflict with the SCL signal from another master is possible. When issuing the start condition would create conflict on the bus, loss of arbitration is detected by testing for non-matching between the internal signal for the SDA line and the level on the SDA line. In master operation, loss of arbitration is detected by testing for non-matching between the signal on the SDA line and the internal signal for the SDA line. • Loss of arbitration due to detection of the start condition while the bus is busy is detectable (to prevent the issuing of double start conditions). • Loss of arbitration in transfer of a not-acknowledge bit due to the internal signal for the SDA line and the level on the SDA line not matching is detectable. • Loss of arbitration due to non-matching of internal and line levels for data is detectable in slave transmission.
Timeout function	• The internal time-out function is capable of detecting long-interval stoppages of the SCL (clock signal).
Noise removal	• The interface incorporates digital noise filters for both the SCL and SDA signals, and the width for noise cancellation by the filters is adjustable.
Interrupt sources	• Four sources: Error in transfer or occurrence of events (detection of AL, NACK, time-out, a start condition including a restart condition, or a stop condition) Receive-data-full (including matching with a slave address) Transmit-data-empty (including matching with a slave address) Transmission complete

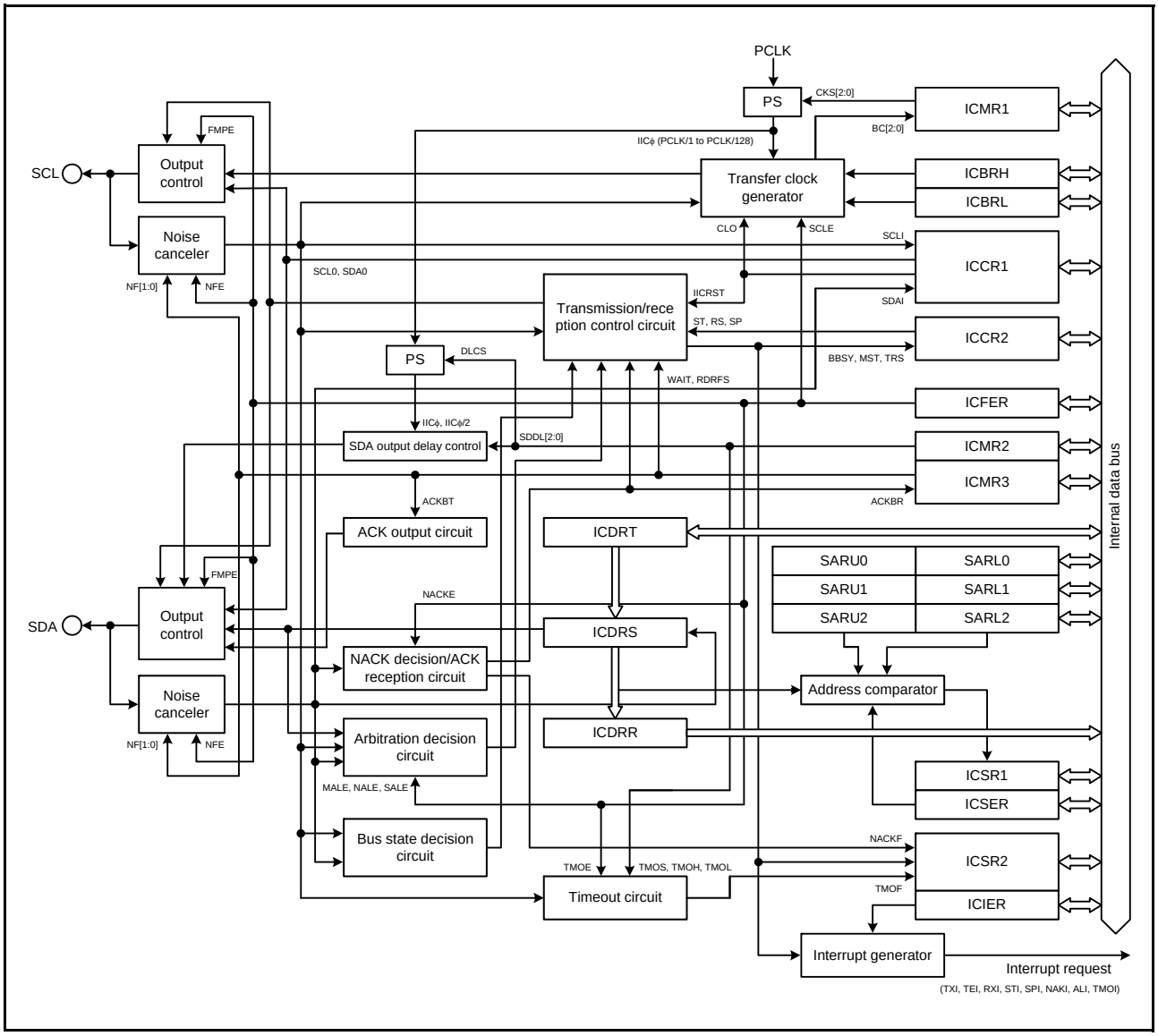


Figure 24.1 Block Diagram of RIIC

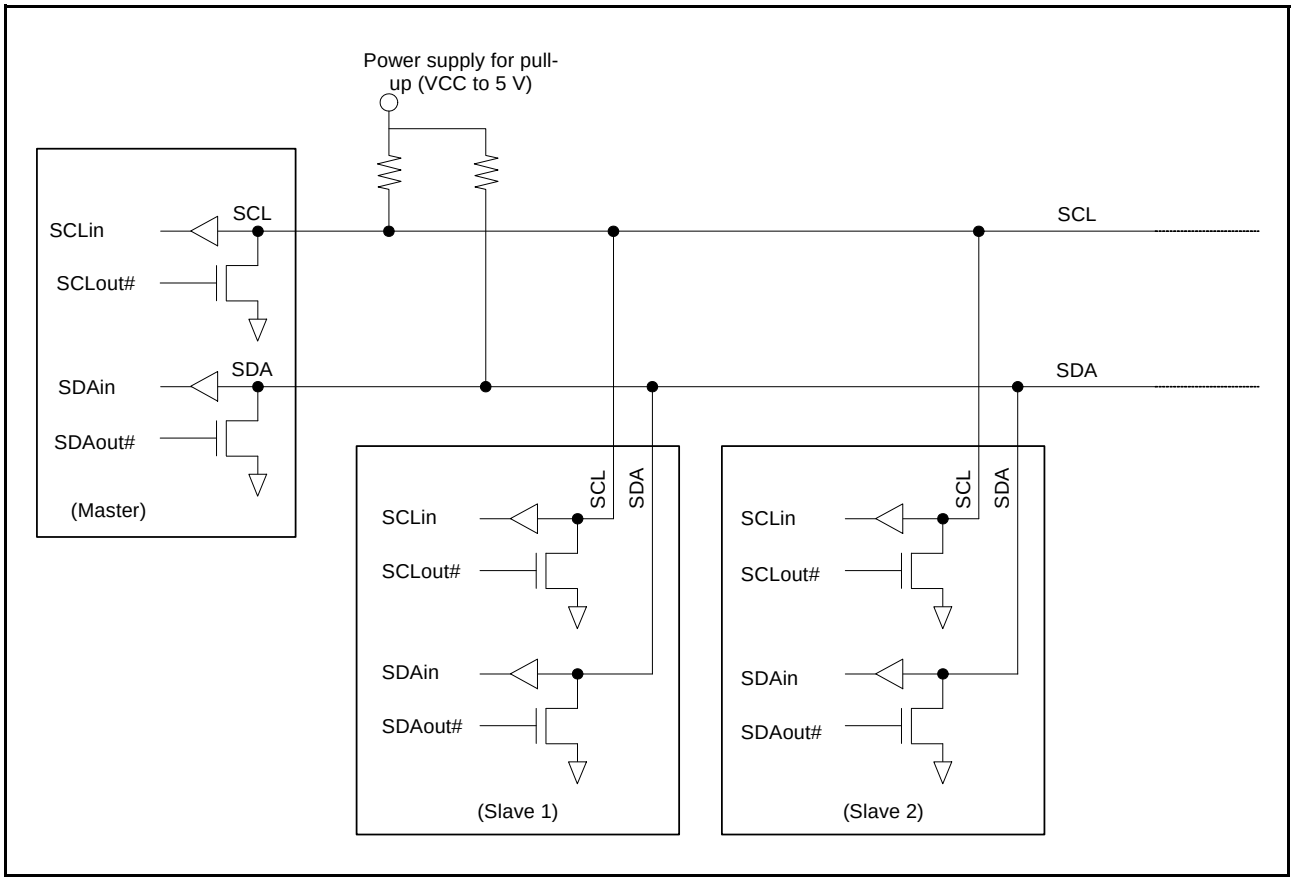


Figure 24.2 Connections to the External Circuit by the I/O Pins (I²C Bus Configuration Example)

Table 24.2 Pin Configuration

Pin Name	I/O	Function
SCL	I/O	Serial clock I/O pin
SDA	I/O	Serial data I/O pin

24.2 Register Descriptions

Table 24.3 lists the registers of the RIIC.

Table 24.3 Registers of the RIIC

Channel	Register Name	Symbol	Value after Reset	Address	Access Size
RIIC0	I²C bus control register 1	ICCR1	1Fh	0008 8300h	8
	I²C bus control register 2	ICCR2	00h	0008 8301h	8
	I²C bus mode register 1	ICMR1	08h	0008 8302h	8
	I²C bus mode register 2	ICMR2	06h	0008 8303h	8
	I²C bus mode register 3	ICMR3	00h	0008 8304h	8
	I²C bus function enable register	ICFER	72h	0008 8305h	8
	I²C bus status enable register	ICSER	09h	0008 8306h	8
	I²C bus interrupt enable register	ICIER	00h	0008 8307h	8
	I²C bus status register 1	ICSR1	00h	0008 8308h	8
	I²C bus status register 2	ICSR2	00h	0008 8309h	8
	Slave address register L0	SARL0	00h	0008 830Ah	8
	Timeout internal counter L	TMOCNTL	0000h	0008 830Ah	16
	Slave address register U0	SARU0	00h	0008 830Bh	8
	Timeout internal counter	TMOCNTU	0000h	0008 830Bh	16
	Slave address register L1	SARL1	00h	0008 830Ch	8
	Slave address register U1	SARU1	00h	0008 830Dh	8
	Slave address register L2	SARL2	00h	0008 830Eh	8
	Slave address register U2	SARU2	00h	0008 830Fh	8
	I²C bus bit rate low-level register	ICBRL	FFh	0008 8310h	8
	I²C bus bit rate high-level register	ICBRH	FFh	0008 8311h	8
	I²C bus transmit data register	ICDRT	FFh	0008 8312h	8
	I²C bus receive data register	ICDRR	00h	0008 8313h	8
	I²C bus shift register	ICDRS	—	—	8

24.2.1 I2C Bus Control Register 1 (ICCR1)

Address: 0008 8300h

	b7	b6	b5	b4	b3	b2	b1	b0
	ICE	IICRST	CLO	SOWP	SCLO	SDAO	SCLI	SDAI
Value after reset:	0	0	0	1	1	1	1	1

Bit	Symbol	Bit Name	Description	R/W
b0	SDAI	SDA Bus Input Monitor	0: SDA pin input is at a low level 1: SDA pin input is at a high level	R
b1	SCLI	SCL Bus Input Monitor	0: SCL pin input is at a low level 1: SCL pin input is at a high level	R
b2	SDAO	SDA Output Control*1*2	Read: 0: SDA pin output is at a low level 1: SDA pin is in a high-impedance state Write: 0: Changes the SDA pin output to a low level 1: Changes the SDA pin in a high-impedance state (High level output is achieved through an external pull-up resistor.)	R/W *1, *2
b3	SCLO	SCL Output Control*1*2	Read: 0: SCL pin output is at a low level 1: SCL pin is in a high-impedance state Write: 0: Changes the SCL pin output to a low level 1: Changes the SCL pin in a high-impedance state (High level output is achieved through an external pull-up resistor.)	R/W *1, *2
b4	SOWP	SCLO/SDAO Write Protect*2	0: Allows the SCLO and SDAO bits to be rewritten (This bit is always read as 1.)	R/W *2
b5	CLO	Extra SCL Clock Cycle Output	0: Does not output an extra SCL clock cycle (default) 1: Outputs an extra SCL clock cycle (The CLO bit is cleared automatically after one clock cycle is output.)	R/W
b6	IICRST	I2C Bus Interface Internal Reset	0: Clears the RIIC reset or internal reset 1: Initiates the RIIC reset or internal reset (Clears the bit counter and the SCL/SDA output latch)	R/W
b7	ICE	I2C Bus Interface Enable	0: Disables the RIIC (the SCL pin and SDA pin function as ports) 1: Enables the RIIC transfer function (the SCL pin and SDA pin drive the bus)	R/W

Note 1. Do not write to these bits during communication. Changing a value during communication may cause a transmission or reception failure or an AL error.
Note 2. To change the SDAO and SCLO bits, set the SOWP bit to 0 at the same timing to set the SDAO and SCLO bits to 0.

ICCR1 enables or disables the RIIC, resets the internal state of the RIIC, outputs an extra SCL clock cycle, and manipulates and monitors the SCL pin and SDA pin.

SDAI Bit (SDA Bus Input Monitor)

This bit monitors the input level of the SDA pin.

SCLI Bit (SCL Bus Input Monitor)

This bit monitors the input level of the SCL pin.

SDAO Bit (SDA Output Control)

This bit controls the output level of the SDA pin. This bit also monitors the output state of the SDA pin.

SCLO Bit (SCL Output Control)

This bit controls the output level of the SCL pin. This bit also monitors the output state of the SCL pin.

SOWP Bit (SCLO/SDAO Write Protect)

This bit controls the modification of the SCLO and SDAO bits.

CLO Bit (Extra SCL Clock Cycle Output)

This bit is used to output an extra SCL clock cycle for debugging or error processing.
Normally, set the bit to 0. Setting the bit to 1 in a normal communication state causes a communication error.
For details on this function, see section 24.11.2, Extra SCL Clock Cycle Output Function.

IICRST Bit (I²C Bus Interface Internal Reset)

This bit is used to reset the internal states of the RIIC.
Setting this bit to 1 initiates an RIIC reset or internal reset.
Whether an RIIC reset or internal reset is initiated is determined according to the combination with the ICE bit. Table 24.4 lists the resets of the RIIC.
The RIIC reset resets all registers including the BBSY flag in ICCR2 and internal states of the RIIC, and the internal reset resets the bit counter (BC[2:0] bits in ICMR1), the I²C bus shift register (ICDRS), and the I²C bus status registers (ICSR1 and ICSR2) as well as the internal states of the RIIC. For the reset conditions for each register, see section 24.14, Reset States.
An internal reset initiated with the IICRST bit set to 1 during operation (with the ICE bit set to 1) resets the internal states of the RIIC without initializing the port settings and the control and setting registers of the RIIC when the bus or RIIC hangs up due to a communication error.
If the RIIC hangs up in a low level output state, resetting the internal states cancels the low level output state and releases the bus with the SCL pin and SDA pin at a high impedance.

Note: • If an internal reset is initiated using the IICRST bit for a bus hang-up occurred during communication with the master device in slave mode, the states may become different between the slave device and the master device (due to the difference in the bit counter information). For this reason, do not initiate an internal reset in slave mode, but initiate restoration processing from the master device. If an internal reset is necessary because the RIIC hangs up with the SCL line in a low level output state in slave mode, initiate an internal reset and then issue a restart condition from the master device or resume communication from the start condition issuance after issuing a stop condition. If communication is restarted by initiating a reset solely in the slave device without issuing a start condition or restart condition from the master device, synchronization will be lost because the master and slave devices operate asynchronously.

Table 24.4 RIIC Resets

IICRST	ICE	State	Specifications
1	0	RIIC reset	Resets all registers and internal states of the RIIC.
	1	Internal reset	Reset the BC[2:0] bits in ICMR1, and the ICSR1, ICSR2, ICDRS registers and the internal states of the RIIC.

ICE Bit (I²C Bus Interface Enable)

This bit is used to enable or disable the transfer operation of the RIIC.

When this bit is set to 0 to disable the RIIC, the SCL pin and SDA pin function as ports. An RIIC reset is initiated by setting the IICRST bit to 1 with the ICE bit set to 0, and an internal reset is initiated by setting the IICRST bit to 1 with the ICE bit set to 1.

To prevent unexpected communications, set the RIIC registers with the ICE bit set to 0 (to disable the RIIC), and set the ICE bit to 1 (to enable the transfer operation) after finishing all register settings.

Note 1. In addition to the I²C bus pin functions, other functions are also multiplexed onto the pins of the RX62T Group. To use the pins as I²C bus pins (SCL pin and SDA pin), disable the other multiplexed functions. Since both of the SCL pin and SDA pin of the I²C bus pins are I/O pins, set the corresponding PORTn.DDR register to 0 (input) and set the PORTn.ICR register to 1 (input buffer enabled).

24.2.2 I²C Bus Control Register 2 (ICCR2)

Address: 0008 8301h

	b7	b6	b5	b4	b3	b2	b1	b0
	BBSY	MST	TRS	—	SP	RS	ST	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b1	ST	Start Condition Issuance Request	0: Does not request to issue a start condition 1: Requests to issue a start condition	R/W
b2	RS	Restart Condition Issuance Request	0: Does not request to issue a restart condition 1: Requests to issue a restart condition	R/W
b3	SP	Stop Condition Issuance Request	0: Does not request to issue a stop condition 1: Requests to issue a stop condition	R/W
b4	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b5	TRS	Transmit/Receive Mode	0: Receive mode 1: Transmit mode	R/W*1
b6	MST	Master/Slave Mode	0: Slave mode 1: Transmit mode	R/W*1
b7	BBSY	Bus Busy Detection Flag	0: The I²C bus is released (bus free state) 1: The I²C bus is occupied (bus busy state or in the bus free state)	R

Note 1. When the MTWP bit in ICMR1 is set to 1, the MST and TRS bits can be written to.

ICCR2 has a flag function that indicates whether or not the I²C bus is occupied and whether the RIIC is in transmit/receive or master/slave mode as well as a function to issue a start or stop condition.

ST Bit (Start Condition Issuance Request)

This bit is used to request transition to master mode and issuance of a start condition.

When this bit is set to 1 to request to issue a start condition, a start condition is issued when the BBSY flag is set to 0 (bus free).

For details on the start condition issuance, see section 24.10, Start Condition/Restart Condition/Stop Condition Issuing Function.

[Setting condition]

- When 1 is written to the ST bit

[Clearing conditions]

- When 0 is written to the ST bit
- When a start condition has been issued
- When the AL (arbitration lost) flag in ICSR2 is set to 1
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

Note: • Set the ST bit to 1 (start condition issuance request) when the BBSY flag is set to 0 (bus free).
Note that arbitration may be lost if the ST bit is set to 1 (start condition issuance request) when the BBSY flag is set to 1 (bus busy).

RS Bit (Restart Condition Issuance Request)

This bit is used to request that a restart condition be issued in master mode.

When this bit is set to 1 to request to issue a restart condition, a restart condition is issued when the BBSY flag is set to 1 (bus busy) and the MST bit is set to 1 (master mode).

For details on the restart condition issuance, see section 24.10, Start Condition/Restart Condition/Stop Condition Issuing Function.

[Setting condition]

- When 1 is written to the RS bit with the BBSY flag in ICCR2 set to 1

[Clearing conditions]

- When 0 is written to the RS bit
- When a restart condition has been issued or a start condition is detected
- When the AL (arbitration lost) flag in ICSR2 is set to 1
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

Note 1. This bit cannot be written to while the BBSY flag is 0 (bus free state).
Note 2. Do not set the RS bit to 1 while issuing a stop condition.
Note 3. If the RS bit is set to 1 (restart condition issuance request) in mode other than master mode, the restart condition is not issued in this mode but the restart condition issuance request bit remains set. If the operating mode changes to master mode with the bit not being cleared, the restart condition may be issued: this may hinder communications or cause an unexpected action.

SP Bit (Stop Condition Issuance Request)

This bit is used to request that a stop condition be issued in master mode.

When this bit is set to 1 to request to issue a stop condition, a stop condition is issued when the BBSY flag is set to 1 (bus busy) and the MST bit is set to 1 (master mode).

For details on the stop condition issuance, see section 24.10, Start Condition/Restart Condition/Stop Condition Issuing Function.

[Setting condition]

- When 1 is written to the SP bit with both the BBSY flag and the MST bit in ICCR2 set to 1

[Clearing conditions]

- When 0 is written to the SP bit after reading SP = 1
- When a stop condition has been issued or a stop condition is detected
- When the AL (arbitration lost) flag in ICSR2 is set to 1
- When a start condition and a restart condition are detected
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

Note 1. Writing to the SP bit is not possible while the setting of the BBSY flag is 0 (bus free).
Note 2. Do not set the SP bit to 1 while a restart condition is being issued.

TRS Bit (Transmit/Receive Mode)

This bit indicates transmit or receive mode.
The RIIC is in receive mode when the TRS bit is set to 0 and is in transmit mode when the bit is set to 1. Combination of this bit and the MST bit indicates the operating mode of the RIIC.
The value of the TRS bit is automatically changed to the value for transmission mode or reception mode by detection or issuing of a start condition, setting or clearing of the R/W# bit, etc. Although writing to the TRS bit is possible when the MTWP bit in ICMR1 is set to 1, writing to this bit is not necessary during normal usage.
[Setting conditions]

- When a start condition is issued normally according to the start condition issuance request (when a start condition is detected with the ST bit set to 1)
- When the R/W# bit added to the slave address is set to 0 in master mode
- When the address received in slave mode matches the address enabled in ICSER, with the R/W# bit set to 1
- When 1 is written to the TRS bit with the MTWP bit in ICMR1 set to 1

[Clearing conditions]

- When a stop condition is detected
- The AL (arbitration lost) flag in ICSR2 being set to 1
- In master mode, reception of a slave address to which an R/W# bit with the value 1 is appended
- In slave mode, a match between the received address and the address enabled in ICSER when the value of the received R/W# bit is 0 (including cases where the received address is the general call address)
- In slave mode, a restart condition is detected (a start condition is detected with ICCR2.BBSY = 1 and ICCR2.MST = 0)
- When 0 is written to the TRS bit with the MTWP bit in ICMR1 set to 1
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

MST Bit (Master/Salve Mode)

This bit indicates master or slave mode.
The RIIC is in slave mode when the MST bit is set to 0 and is in master mode when the bit is set to 1. Combination of this bit and the TRS bit indicates the operating mode of the RIIC.
The value of the MST bit is automatically changed to the value for master mode or slave mode by detection or issuing of a start condition, etc. Although writing to the MST bit is possible when the MTWP bit in ICMR1 is set to 1, writing to this bit is not necessary during normal usage.
[Setting conditions]

- When a start condition is issued normally according to the start condition issuance request (when a start condition is detected with the ST bit set to 1)
- When 1 is written to the MST bit with the MTWP bit in ICMR1 set to 1

[Clearing conditions]

- When a stop condition is detected
- When the AL (arbitration lost) flag in ICSR2 is set to 1
- When 0 is written to the MST bit with the MTWP bit in ICMR1 set to 1
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

BBSY Flag (Bus Busy Detection)

The BBSY flag indicates whether the I^2C bus is occupied (bus busy) or released (bus free).
This bit is set to 1 when the SDA line changes from high to low under the condition of SCL = high, assuming that a start condition has been issued.
When the SDA line changes from low to high under the condition of SCL = high, this bit is cleared to 0 after the bus free time (specified in ICBRL) start condition is not detected, assuming that a stop condition has been issued.
[Setting condition]

- When a start condition is detected

[Clearing conditions]

- When the bus free time (specified in ICBRL) start condition is not detected after detecting a stop condition
- When 1 is written to the IICRST bit in ICCR1 with the ICE bit in ICCR1 set to 0 (RIIC reset)

24.2.3 I2C Bus Mode Register 1 (ICMR1)

Address: 0008 8302h

	b7	b6	b5	b4	b3	b2	b1	b0
	MTWP	CKS[2:0]			BCWP	BC[2:0]		
Value after reset:	0	0	0	0	1	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b2 to b0	BC[2:0]]	Bit Counter*1	b2 b1 b0 0 0 0: 9 bits 0 0 1: 2 bits 0 1 0: 3 bits 0 1 1: 4 bits 1 0 0: 5 bits 1 0 1: 6 bits 1 1 0: 7 bits 1 1 1: 8 bits	R/W*1
b3	BCWP	BC Write Protect*1	0: Enables a value to be written in the BC[2:0] bits (This bit is always read as 1.)	R/W*1
b6 to b4	CKS[2:0]	Internal Reference Clock Selection	b6 b5 b4 0 0 0: PCLK/1 clock 0 0 1: PCLK/2 clock 0 1 0: PCLK/4 clock 0 1 1: PCLK/8 clock 1 0 0: PCLK/16 clock 1 0 1: PCLK/32 clock 1 1 0: PCLK/64 clock 1 1 1: PCLK/128 clock	R/W
b7	MTWP	MST/TRS Write Protect	0: Disables writing to the MST and TRS bits in ICCR2 1: Enables writing to the MST and TRS bits in ICCR2	R/W

Note 1. Set the BCWP bit to 0 to rewrite the BC[2:0] bits. The BC[2:0] bits must be rewritten by using the MOV instruction.

ICMR1 specifies the internal reference clock source within the RIIC, indicates the number of bits to be transferred, and protects the MST and TRS bits in ICCR2 from being written.

BC[2:0] Bits (Bit Counter)

These bits function as a counter that indicates the number of bits remaining to be transferred at the detection of a rising edge on the SCL line. Although these bits are writable and readable, it is not necessary to access these bits under normal conditions.

To write to these bits, specify the number of bits to be transferred plus one (data is transferred with an additional acknowledge bit) between transferred frames when the SCL line is at a low level.

The values of the BC[2:0] bits return to 000b at the end of a data transfer including the acknowledge bit or when a start condition including a restart condition is detected.

BCWP Bit (BC Write Protect)

This bit enables a value to be written in the BC[2:0] bits.

CKS[2:0] Bits (Internal Reference Clock Selection)

These bits select a reference clock source (IICϕ) inside the RIIC.

MTWP Bit (MST/TRS Write Protect)

This bit controls the modification of the MST and TRS bits in ICCR2.

24.2.4 I²C Bus Mode Register 2 (ICMR2)

Address: 0008 8303h

	b7	b6	b5	b4	b3	b2	b1	b0
	DLCS	SDDL[2:0]			TMWE	TMOH	TMOL	TMOS
Value after reset:	0	0	0	0	0	1	1	0

Bit	Symbol	Bit Name	Description	R/W
b0	TMOS	Timeout Detection Time Selection	0: Long mode is selected 1: Short mode is selected	R/W
b1	TMOL	Timeout L Count Control	0: Count is disabled while the SCL line is at a low level 1: Count is enabled while the SCL line is at a low level	R/W
b2	TMOH	Timeout H Count Control	0: Count is disabled while the SCL line is at a high level 1: Count is enabled while the SCL line is at a high level	R/W
b3	TMWE	Timeout internal counter write enable bit	0: Writing to internal counter of timeout detection function is disabled. 1: Writing to internal counter of timeout detection function is enabled.	R/W
b6 to b4	SDDL[2:0]	SDA Output Delay Counter	When ICMR2.DLCS = 0 (IICϕ) b6 b4 0 0 0: No output delay 0 0 1: 1 IICϕ cycle 0 1 0: 2 IICϕ cycles 0 1 1: 3 IICϕ cycles 1 0 0: 4 IICϕ cycles 1 0 1: 5 IICϕ cycles 1 1 0: 6 IICϕ cycles 1 1 1: 7 IICϕ cycles When ICMR2.DLCS = 1 (IICϕ/2) b6 b4 0 0 0: No output delay 0 0 1: 1 or 2 IICϕ cycles 0 1 0: 3 or 4 IICϕ cycles 0 1 1: 5 or 6 IICϕ cycles 1 0 0: 7 or 8 IICϕ cycles 1 0 1: 9 or 10 IICϕ cycles 1 1 0: 11 or 12 IICϕ cycles 1 1 1: 13 or 14 IICϕ cycles	R/W
b7	DLCS	SDA Output Delay Clock Source Selection	0: The internal reference clock (IICϕ) is selected as the clock source of the SDA output delay counter 1: The internal reference clock divided by 2 (IICϕ/2) is selected as the clock source of the SDA output delay counter*1	R/W

Note 1. The selection DLCS = 1 (IICϕ/2) is only effective when the SCL signal is at the low level. Setting DLCS = 1 while SCL is high is ineffective, and the internal reference clock (IICϕ) will be selected.

ICMR2 has a timeout function and an SDA output delay function.

TMOS Bit (Timeout Detection Time Selection)

This bit is used to select long mode or short mode for the timeout detection time when the timeout function is enabled (TMOE bit = 1 in ICFER). When this bit is set to 0, long mode is selected. When this bit is set to 1, short mode is selected. In long mode, the timeout detection internal counter functions as a 16 bit-counter. In short mode, the counter functions as a 14 bit-counter. While the SCL line is in the state that enables this counter as specified by bits TMOH and TMOL, the counter counts up in synchronization with the internal reference clock (IICϕ) as a count source.
For details on the timeout function, see section 24.11.1, Timeout Function.

TMOL Bit (Timeout L Count Control)

This bit is used to enable or disable the internal counter of the timeout function to count up while the SCL line is held low when the timeout function is enabled (TMOE bit = 1 in ICFER).

TMOH Bit (Timeout H Count Control)

This bit is used to enable or disable the internal counter of the timeout function to count up while the SCL line is held high when the timeout function is enabled (TMOE bit = 1 in ICFER).

TMWE Bit (Timeout internal counter write enable bit)

This bit is used to enable or disable writing to Timeout internal counter (TMOCNT_L/U).
When this bit is set to “1”, the address of timeout internal counter (TMOCNT_L/U) is allocated to the address of SARL0/ SARU0.

SDDL[2:0] Bits (SDA Output Delay Setup Counter)

The SDA output can be delayed by the SDDL[2:0] setting. This counter works with the clock source selected by the DLCS bit. The setting of this function can be used for all types of SDA output, including the transmission of the acknowledge bit.
For details on this function, see section 24.5, Facility for Delaying SDA Output.

Note 1. Set the SDA output delay time to meet the I^2C bus standard (within the data enable time/acknowledge enable time*2) or the SMBus standard (within the data hold time: 300 ns or more, and SCL-clock low-level period – the data setup time: 250 ns). Note that, if a value outside the standard is set, communication with communication devices may malfunction or it may seemingly become a start condition or stop condition depending on the bus state.

Note 2. Data enable time/acknowledge enable time
3,450 ns (up to 100 kbps: standard mode [Sm])
900 ns (up to 400 kbps: fast mode [fm])

DLCS bit (SDA Output Delay Clock Source Selection)

This bit is used to select the internal reference clock (IICϕ) or the internal reference clock divided by 2 (IICϕ/2) as the clock source of the SDA output delay time.
The selection DLCS = 1 (IICϕ/2) is only effective when the SCL signal is at the low level.
Setting DLCS = 1 while SCL is high is ineffective, and the internal reference clock (IICϕ) will be selected.

24.2.5 I²C Bus Mode Register 3 (ICMR3)

Address: 0008 8304h

	b7	b6	b5	b4	b3	b2	b1	b0
	SMBS	WAIT	RDRFS	ACKWP	ACKBT	ACKBR	NF[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1, b0	NF[1:0]	Noise Filter Stage Selection	b1 b0 0 0: Noise of up to 1-IICϕ range is filtered out (single-stage filter) 0 1: Noise of up to 2- IICϕ range is filtered out (2-stage filter) 1 0: Noise of up to 3- IICϕ range is filtered out (3-stage filter) 1 1: Noise of up to 4- IICϕ range is filtered out (4-stage filter)	R/W
b2	ACKBR	Receive Acknowledge	0: A 0 is received as the acknowledge bit (ACK reception) 1: A 1 is received as the acknowledge bit (NACK reception)	R
b3	ACKBT	Transmit Acknowledge	0: A 0 is sent as the acknowledge bit (ACK transmission) 1: A 1 is sent as the acknowledge bit (NACK transmission)	R/W *1
b4	ACKWP	ACKBT Write Protect	0: Modification of the ACKBT bit is disabled 1: Modification of the ACKBT bit is enabled*1	W*1
b5	RDRFS	RDRF Flag Set Timing Selection	0: The RDRF flag is set at the rising edge of the ninth SCL clock cycle (The SCL line is not held low at the falling edge of the eighth clock cycle.) 1: The RDRF flag is set at the rising edge of the eighth SCL clock cycle (The SCL line is held low at the falling edge of the eighth clock cycle.) Low-hold is released by writing a value to the ACKBT bit	R/W *2
b6	WAIT	WAIT	0: No WAIT (The period between ninth clock cycle and first clock cycle is not held low.) 1: WAIT (The period between ninth clock cycle and first clock cycle is held low.) Low-hold is released by reading ICDRR	R/W *2
b7	SMBS	SMBus/I²C Bus Selection	0: The I²C bus is selected 1: The SMBus is selected	R/W

Note 1. If it is attempted to write 1 to both ACKWP and ACKBT bits, the ACKBT bit cannot be set to 1.
Note 2. The WAIT and RDRFS bits are valid only in receive mode (invalid in transmit mode).

ICMR3 has functions to send/receive acknowledge and to select the RDRF set timing in RIIC receive operation, WAIT operation, and the SCL pin and SDA pin input level of the RIIC.

NF[1:0] Bits (Noise Filter Stage Selection)

These bits are used to select the number of stages of the digital noise filter.

Note 1. Set the noise range to be filtered out by the noise filter within a range less than the SCL line high-level period or low-level period. If the noise range is set to a value of (SCL clock width: high-level period or low-level period, whichever is shorter) – [1.5 internal reference clock sync (IICϕ) cycles + analog noise filter: 120 ns (reference value)] or more, the SCL clock is regarded as noise by the noise filter function of the RIIC, which may prevent the RIIC from operating normally.

ACKBR Bit (Receive Acknowledge)

This bit is used to store the acknowledge bit information received from the receive device in transmit mode.
[Setting condition]

- When a 1 is received as the acknowledge bit with the TRS bit in ICCR2 set to 1

[Clearing conditions]

- When a 0 is received as the acknowledge bit with the TRS bit in ICCR2 set to 1
- When 1 is written to the IICRST bit in ICCR1 while the ICE bit in ICCR1 is 0 (RIIC reset)

ACKBT Bit (Transmit Acknowledge)

This bit is used to set the bit to be sent at the acknowledge timing in receive mode.
[Setting condition]

- When 1 is written to this bit with the ACKWP bit set to 1

[Clearing conditions]

- When 0 is written to this bit with the ACKWP bit set to 1
- When stop condition issuance is detected (when a stop condition is detected with the SP bit in ICCR2 set to 1)
- When 1 is written to the IICRST bit in ICCR1 while the ICE bit in ICCR1 is 0 (RIIC reset)

Note: • The ACKBT bit must be modified while the ACKWP bit is 1. If the ACKBT bit is modified with the ACKWP bit cleared to 0, writing to the ACKBT bit is disabled.

ACKWP Bit (ACKBT Write Protect)

This bit is used to control the modification of the ACKBT bit.

RDRFS Bit (RDRF Flag Set Timing Selection)

This bit is used to select the RDRF flag set timing in receive mode and also to select whether to hold the SCL line low at the falling edge of the eighth SCL clock cycle.
When the RDRFS bit is 0, the SCL line is not held low at the falling edge of the eighth SCL clock cycle, and the RDRF flag is set to 1 at the rising edge of the ninth SCL clock cycle.
When the RDRFS bit is 1, the RDRF flag is set to 1 at the rising edge of the eighth SCL clock cycle and the SCL line is held low at the falling edge of the eighth SCL clock cycle. The low-hold of the SCL line is released by writing a value to the ACKBT bit.
After data is received with this setting, the SCL line is automatically held low before the acknowledge bit is sent. This enables processing to send ACK (ACKBT = 0) or NACK (ACKBT = 1) according to receive data.

WAIT Bit (WAIT)

This bit is used to control whether to hold the period between the ninth SCL clock cycle and the first SCL clock cycle low until the receive data buffer (ICDRR) is completely read each time single-byte data is received in receive mode.
When the WAIT bit is 0, the receive operation is continued without holding the period between the ninth and the first SCL clock cycle low. When both the RDRFS and WAIT bits are 0, continuous receive operation is enabled with the double buffer.
When the WAIT bit is 1, the SCL line is held low from the falling edge of the ninth clock cycle until the ICDRR value is read each time single-byte data is received. This enables receive operation in byte units.
Note: When the value of the WAIT bit is to be read, be sure to read the ICDRR beforehand.

SMBS Bit (SMBus/I²C Bus Selection)

Setting this bit to 1 selects the SMBus and enables the HOAE bit in ICSER.

24.2.6 I2C Bus Function Enable Register (ICFER)

Address: 0008 8305h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	SCLE	NFE	NACKE	SALE	NALE	MALE	TMOE
Value after reset:	0	1	1	1	0	0	1	0

Bit	Symbol	Bit Name	Description	R/W
b0	TMOE	Timeout Function Enable	0: The timeout function is disabled 1: The timeout function is enabled	R/W
b1	MALE	Master Arbitration Lost Detection Enable	0: Master arbitration lost detection is disabled (Disables the arbitration lost detection function and does not clear the MST and TRS bits in ICCR2 automatically when arbitration is lost.) 1: Master arbitration lost detection is enabled (Enables the arbitration lost detection function and clears the MST and TRS bits in ICCR2 automatically when arbitration is lost.)	R/W
b2	NALE	NACK Transmission Arbitration Lost Detection Enable	0: NACK transmission arbitration lost detection is disabled 1: NACK transmission arbitration lost detection is enabled	R/W
b3	SALE	Slave Arbitration Lost Detection Enable	0: Slave arbitration lost detection is disabled 1: Slave arbitration lost detection is enabled	R/W
b4	NACKE	NACK Reception Transfer Suspension Enable	0: Transfer operation is not suspended during NACK reception (transfer suspension disabled) 1: Transfer operation is suspended during NACK reception (transfer suspension enabled)	R/W
b5	NFE	Digital Noise Filter Circuit Enable	0: No digital noise filter circuit is used 1: A digital noise filter circuit is used	R/W
b6	SCLE	SCL Synchronous Circuit Enable	0: No SCL synchronous circuit is used 1: An SCL synchronous circuit is used	R/W
b7	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W

ICFER enables or disables the timeout function, the arbitration lost detection function, and the receive operation suspension function during NACK reception, and selects the use of a digital noise filter circuit and SCL synchronous circuit.

TMOE Bit (Timeout Function Enable)

This bit is used to enable or disable the timeout function.
For details on the timeout function, see section 24.11.1, Timeout Function.

MALE Bit (Master Arbitration Lost Detection Enable)

This bit is used to specify whether to use the arbitration lost detection function in master mode. Normally, set this bit to 1.

NALE Bit (NACK Transmission Arbitration Lost Detection Enable)

This bit is used to specify whether to cause arbitration to be lost when ACK is detected during transmission of NACK in receive mode (such as when slaves with the same address exist on the bus or when two or more masters select the same slave device simultaneously with different number of receive bytes).

SALE Bit (Slave Arbitration Lost Detection Enable)

This bit is used to specify whether to cause arbitration to be lost when a value different from the value being transmitted is detected on the bus in slave transmit mode (such as when slaves with the same address exist on the bus or when a mismatch with the transmit data occurs due to noise).

NACKE Bit (NACK Reception Transfer Suspension Enable)

This bit is used to specify whether to continue or discontinue the transfer operation when NACK is received from the slave device in transmit mode. Normally, set this bit to 1.
When NACK is received with the NACKE bit set to 1, the next transfer operation is suspended.
When the NACKE bit is 0, the next transfer operation is continued regardless of the received acknowledge content.
For details on the NACK reception transfer suspension function, see section 24.8.2, NACK Reception Transfer Suspension Function.

NFE Bit (Digital Noise Filter Circuit Enable)

This bit is used to specify whether to use a digital noise filter circuit.

SCLE Bit (SCL Synchronous Circuit Enable)

This bit is used to specify whether to synchronize the SCL clock with the SCL input clock. Normally, set this bit to 1.
When the SCLE bit is cleared to 0 (SCL synchronous circuit not used), the RIIC does not synchronize the SCL clock with the SCL input clock (by detecting the SCL line level) for the SCL clock output operation in master mode, and the RIIC outputs the SCL clock with the transfer rate set in ICBRH and ICBRL regardless of the SCL line state. For this reason, if the bus load of the I^2C bus line is much larger than the specification value or if the SCL clock output overlaps in multiple masters, the short-cycle SCL clock that does not meet the specification may be output. When no SCL synchronous circuit is used, it also affects the issuance of a start condition, restart condition, and stop condition, and the continuous output of extra SCL clock cycles.
This bit must not be cleared to 0 except for checking the output of the transfer rate that was set during debugging.

FMPE Bit (Fast-mode Plus Enable)

This bit is used to specify whether to use a slope control circuit for Fast-mode Plus[fm+].
When this bit is set to 1, a slope control circuit conforming to the Fast-mode Plus[fm+] slope control standard (tof) of the I^2C bus is selected. When this bit is cleared to 0, a slope control circuit conforming to the Standard-mode[Sm] and Fast-mode[fm] slope control standard (tof) of the I^2C bus is selected.
Set this bit to 1 when using the transmission rate within a range up to 1 Mbps (Fast-mode Plus[fm+]) of the I^2C bus standard. Clear this bit to 0 when using the transmission rate at other rates (up to 100 kbps[Sm], up to 400 kbps[fm]) or for SMBus (10 to 100 kbps).

24.2.7 I2C Bus Status Enable Register (ICSER)

Address: 0008 8306h

	b7	b6	b5	b4	b3	b2	b1	b0
	HOAE	—	DIDE	—	GCAE	SAR2E	SAR1E	SAR0E
Value after reset:	0	0	0	0	1	0	0	1

Bit	Symbol	Bit Name	Description	R/W
b0	SAR0E	Slave Address Register 0 Enable	0: Slave address in SARL0 and SARU0 is disabled 1: Slave address in SARL0 and SARU0 is enabled	R/W
b1	SAR1E	Slave Address Register 1 Enable	0: Slave address in SARL1 and SARU1 is disabled 1: Slave address in SARL1 and SARU1 is enabled	R/W
b2	SAR2E	Slave Address Register 2 Enable	0: Slave address in SARL2 and SARU2 is disabled 1: Slave address in SARL2 and SARU2 is enabled	R/W
b3	GCAE	General Call Address Enable	0: General call address detection is disabled 1: General call address detection is enabled	R/W
b4	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b5	DIDE	Device-ID Address Detection Enable	0: Device-ID address detection is disabled 1: Device-ID address detection is enabled	R/W
b6	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b7	HOAE	Host Address Enable	0: Host address detection is disabled 1: Host address detection is enabled	R/W

ICSER enables or disables comparison of slave addresses, general call address detection, device-ID command detection, and host address detection.

SARyE Bit (Slave Address Register y Enable) (y = 0 to 2)

This bit is used to enable or disable the received slave address and the slave address set in SARLy and SARUy.

When this bit is set to 1, the slave address set in SARLy and SARUy is enabled and is compared with the received slave address.

When this bit is cleared to 0, the slave address set in SARLy and SARUy is disabled and is ignored even if it matches the received slave address.

GCAE Bit (General Call Address Enable)

This bit is used to specify whether to ignore the general call address (0000 000b + 0 [W]: All 0) when it is received.

When this bit is set to 1, if the received slave address matches the general call address, the RIIC recognizes the received slave address as the general call address independently of the slave addresses set in SARLy and SARUy (y = 0 to 2) and performs data receive operation.

When this bit is cleared to 0, the received slave address is ignored even if it matches the general call address.

DIDE Bit (Device-ID Address Detection Enable)

This bit is used to specify whether to recognize and execute the Device-ID address when a device ID (1111 100b) is received in the first frame after a start condition or restart condition is detected.

When this bit is set to 1, if the received first frame matches the device ID, the RIIC recognizes that the Device-ID address has been received. When the following R/W# bit is 0 [W], the RIIC recognizes the second and the following frames as slave addresses and continues the receive operation.

When this bit is cleared to 0, the RIIC ignores the received first frame even if it matches the device ID address and recognizes the first frame as a normal slave address.

For details on the device-ID address detection, see section 24.7.3, Device-ID Address Detection.

HOAE Bit (Host Address Enable)

This bit is used to specify whether to ignore received host address (0001 000b) when the SMBS bit in ICMR3 is 1.

When this bit is set to 1 while the SMBS bit in ICMR3 is 1, if the received slave address matches the host address, the RIIC recognizes the received slave address as the host address independently of the slave addresses set in SARLy and SARUy (y = 0 to 2) and performs the receive operation.

When the SMBS bit in ICMR3 or the HOAE bit is cleared to 0, the received slave address is ignored even if it matches the host address.

24.2.8 I²C Bus Interrupt Enable Register (ICIER)

Address: 0008 8307h

	b7	b6	b5	b4	b3	b2	b1	b0
	TIE	TEIE	RIE	NAKIE	SPIE	STIE	ALIE	TMOIE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	TMOIE	Timeout Interrupt Enable	0: Timeout interrupt request (TMOI) is disabled 1: Timeout interrupt request (TMOI) is enabled	R/W
b1	ALIE	Arbitration Lost Interrupt Enable	0: Arbitration lost interrupt request (ALI) is disabled 1: Arbitration lost interrupt request (ALI) is enabled	R/W
b2	STIE	Start Condition Detection Interrupt Enable	0: Start condition detection interrupt request (STI) is disabled 1: Start condition detection interrupt request (STI) is enabled	R/W
b3	SPIE	Stop Condition Detection Interrupt Enable	0: Stop condition detection interrupt request (SPI) is disabled 1: Stop condition detection interrupt request (SPI) is enabled	R/W
b4	NAKIE	NACK Reception Interrupt Enable	0: NACK reception interrupt request (NAKI) is disabled 1: NACK reception interrupt request (NAKI) is enabled	R/W
b5	RIE	Receive Data Full Interrupt Enable	0: Receive data full interrupt request (ICRXI) is disabled 1: Receive data full interrupt request (ICRXI) is enabled	R/W
b6	TEIE	Transmit End Interrupt Enable	0: Transmit end interrupt request (ICTEI) is disabled 1: Transmit end interrupt request (ICTEI) is enabled	R/W
b7	TIE	Transmit Data Empty Interrupt Enable	0: Transmit data empty interrupt request (ICTXI) is disabled 1: Transmit data empty interrupt request (ICTXI) is enabled	R/W

ICIER enables or disables various interrupt sources.

TMOIE Bit (Timeout Interrupt Enable)

This bit is used to enable or disable timeout interrupt requests (TMOI) when the TMOF flag in ICSR2 is set to 1. A TMOI interrupt request is canceled by clearing the TMOF flag or the TMOIE bit to 0.

ALIE Bit (Arbitration Lost Interrupt Enable)

This bit is used to enable or disable arbitration lost interrupt requests (ALI) when the AL flag in ICSR2 is set to 1. An ALI interrupt request is canceled by clearing the AL flag or the ALIE bit to 0.

STIE Bit (Start Condition Detection Interrupt Enable)

This bit is used to enable or disable start condition detection interrupt requests (STI) when the START flag in ICSR2 is set to 1. An STI interrupt request is canceled by clearing the START flag or the STIE bit to 0.

SPIE Bit (Stop Condition Detection Interrupt Enable)

This bit is used to enable or disable stop condition detection interrupt requests (SPI) when the STOP flag in ICSR2 is set to 1. An SPI interrupt request is canceled by clearing the STOP flag or the SPIE bit to 0.

NAKIE Bit (NACK Reception Interrupt Enable)

This bit is used to enable or disable NACK reception interrupt requests (NAKI) when the NACKF flag in ICSR2 is set to 1. An NAKI interrupt request is canceled by clearing the NACKF flag or the NAKIE bit to 0.

RIE Bit (Receive Data Full Interrupt Enable)

This bit is used to enable or disable receive data full interrupt requests (ICRXI) when the RDRF flag in ICSR2 is set to 1.

TEIE Bit (Transmit End Interrupt Enable)

This bit is used to enable or disable transmit end interrupts (ICTEI) when the TEND flag in ICSR2 is set to 1. An ICTEI interrupt request is canceled by clearing the TEND flag or the TEIE bit to 0.

TIE Bit (Transmit Data Empty Interrupt Enable)

This bit is used to enable or disable transmit data empty interrupts (ICTXI) when the TDRE flag in ICSR2 is set to 1.

24.2.9 I²C Bus Status Register 1 (ICSR1)

Address: 0008 8308h

	b7	b6	b5	b4	b3	b2	b1	b0
	HOA	—	DID	—	GCA	AAS2	AAS1	AAS0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	AAS0	Slave Address 0 Detection Flag	0: Slave address 0 is not detected 1: Slave address 0 is detected • This bit is set to 1 when the received slave address matches the SVA[6:0] value in SARL0 while the FS bit in SARU0 is 0 (7-bit address format selected). • This bit is set to 1 when the received slave address matches a value of (1111 0b + SVA [1:0] in SARU0) and the following address matches the SARL0 value while the FS bit in SARU0 is 1 (10-bit address format selected). (This bit is set at the rising edge of the ninth SCL clock cycle in the SARL0 match determination frame.)	R/(W) *1
b1	AAS1	Slave Address 1 Detection Flag	0: Slave address 1 is not detected 1: Slave address 1 is detected • This bit is set to 1 when the received slave address matches the SVA[6:0] value in SARL1 while the FS bit in SARU1 is 0 (7-bit address format selected). • This bit is set to 1 when the received slave address matches a value of (1111 0b + SVA [1:0] in SARU1) and the following address matches the SARL1 value while the FS bit in SARU1 is 1 (10-bit address format selected). (This bit is set at the rising edge of the ninth SCL clock cycle in the SARL1 match determination frame.)	R/(W) *1
b2	AAS2	Slave Address 2 Detection Flag	0: Slave address 2 is not detected 1: Slave address 2 is detected • This bit is set to 1 when the received slave address matches the SVA[6:0] value in SARL2 while the FS bit in SARU2 is 0 (7-bit address format selected). • This bit is set to 1 when the received slave address matches a value of (1111 0b + SVA [1:0] in SARU2) and the following address matches the SARL2 value while the FS bit in SARU2 is 1 (10-bit address format selected). (This bit is set at the rising edge of the ninth SCL clock cycle in the SARL2 match determination frame.)	R/(W) *1
b3	GCA	General Call Address Detection Flag	0: General call address is not detected 1: General call address is detected • This bit is set to 1 when the received slave address matches the general call address (all 0).	R/(W) *1
b4	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b5	DID	Device-ID Command Detection Flag	0: Device-ID command is not detected 1: Device-ID command is detected • This bit is set to 1 when the first frame received immediately after a start condition is detected matches a value of (device ID (1111 100b) + 0 [W]).	R/(W) *1
b6	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b7	HOA	Host Address Detection Flag	0: Host address is not detected 1: Host address is detected • This bit is set to 1 when the received slave address matches the host address (0001 000b).	R/(W) *1

Note 1. Only 0 can be written to clear the flag.

ICSR1 indicates various address detection statuses.

AASy Flag (Slave Address y Detection) (y = 0 to 2)

[Setting conditions]

<For 7-bit address format: SARUy.FS = 0>

- When the received slave address matches the SVA[6:0] value in SARLy with the SARyE bit in ICSER set to 1 (slave address m detection enabled)
  This flag is set to 1 at the rising edge of the ninth SCL clock cycle in the frame.

<For 10-bit address format: SARUy.FS = 1>

- When the received slave address matches a value of (1111 0b + SVA [1:0] in SARUy) and the following address matches the SARLy value with the SARyE bit in ICSER set to 1 (slave address m detection enabled)
  This flag is set to 1 at the rising edge of the ninth SCL clock cycle in the frame.

[Clearing conditions]

- When 0 is written to the AASy bit after reading AASy = 1
- When a stop condition is detected
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

<For 7-bit address format: SARUy.FS = 0>

- When the received slave address does not match the SVA[6:0] value in SARLy with the SARyE bit in ICSER set to 1 (slave address m detection enabled)
  This flag is cleared to 0 at the rising edge of the ninth SCL clock cycle in the frame.

<For 10-bit address format: SARUy.FS = 1>

- When the received slave address does not match a value of (1111 0b + SVA [1:0] in SARUy) with the SARyE bit in ICSER set to 1 (slave address m detection enabled)
  This flag is cleared to 0 at the rising edge of the ninth SCL clock cycle in the frame.
- When the received slave address matches a value of (1111 0b + SVA [1:0] in SARUy) and the following address does not match the SARLy value with the SARyE bit in ICSER set to 1 (slave address m detection enabled)
  This flag is cleared to 0 at the rising edge of the ninth SCL clock cycle in the frame.

GCA Flag (General Call Address Detection)

[Setting condition]

- When the received slave address matches the general call address (0000 000b + 0 [W]) with the GCAE bit in ICSER set to 1 (general call address detection enabled)
  This flag is set to 1 at the rising edge of the ninth SCL clock cycle in the frame.

[Clearing conditions]

- When 0 is written to the GCA bit after reading GCA = 1
- When a stop condition is detected
- When the received slave address does not match the general call address (0000 000b + 0 [W]) with the GCAE bit in ICSER set to 1 (general call address detection enabled)
  This flag is cleared to 0 at the rising edge of the ninth SCL clock cycle in the frame.
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

DID Flag (Device-ID Address Detection)

[Setting condition]

- When the first frame received immediately after a start condition or restart condition is detected matches a value of (device ID (1111 100b) + 0 [W]) with the DIDE bit in ICSER set to 1 (Device-ID address detection enabled)
  This flag is set to 1 at the rising edge of the ninth SCL clock cycle in the frame.

[Clearing conditions]

- When 0 is written to the DID bit after reading DID = 1
- When a stop condition is detected
- When the first frame received immediately after a start condition or restart condition is detected does not match a value of (device ID (1111 100b)) with the DIDE bit in ICSER set to 1 (Device-ID address detection enabled)
  This flag is cleared to 0 at the rising edge of the ninth SCL clock cycle in the frame.
- When the first frame received immediately after a start condition or restart condition is detected matches a value of (device ID (1111 100b) + 0 [W]) and the second frame does not match any of slave addresses 0 to 2 with the DIDE bit in ICSER set to 1 (Device-ID address detection enabled)
  This flag is cleared to 0 at the rising edge of the ninth SCL clock cycle in the frame.
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

HOA Flag (Host Address Detection)

[Setting condition]

- When the received slave address matches the host address (0001 000b) with the HOAE bit in ICSER set to 1 (host address detection enabled)
  This flag is set to 1 at the rising edge of the ninth SCL clock cycle in the frame.

[Clearing conditions]

- When 0 is written to the HOA bit after reading HOA = 1
- When a stop condition is detected
- When 0 is written to the SMBS bit in ICMR3 or the HOAE bit in ICSER
- When the received slave address does not match the host address (0001 000b) with the HOAE bit in ICSER set to 1 (host address detection enabled)
  This flag is cleared to 0 at the rising edge of the ninth SCL clock cycle in the frame.
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

24.2.10 I2C Bus Status Register 2 (ICSR2)

Address: 0008 8309h

	b7	b6	b5	b4	b3	b2	b1	b0
	TDRE	TEND	RDRF	NACKF	STOP	START	AL	TMOF
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	TMOF	Timeout Detection Flag	0: Timeout is not detected 1: Timeout is detected	R/(W) *1
b1	AL	Arbitration Lost Flag	0: Arbitration is not lost 1: Arbitration is lost	R/(W) *1
b2	START	Start Condition Detection Flag	0: Start condition is not detected 1: Start condition is detected	R/(W) *1
b3	STOP	Stop Condition Detection Flag	0: Stop condition is not detected 1: Stop condition is detected	R/(W) *1
b4	NACKF	NACK Detection Flag	0: NACK is not detected 1: NACK is detected	R/(W) *1
b5	RDRF	Receive Data Full Flag	0: ICDRR contains no receive data 1: ICDRR contains receive data	R/(W) *1
b6	TEND	Transmit End Flag	0: Data is being transmitted 1: Data has been transmitted	R/(W) *1
b7	TDRE	Transmit Data Empty Flag	0: ICDRT contains transmit data 1: ICDRT contains no transmit data	R

Note 1. Only 0 can be written to clear the flag.

ICSR2 indicates various interrupt request flags and statuses.

TMOF Flag (Timeout Detection)

This flag is set to 1 when the RIIC recognizes timeout after the SCL line state remains unchanged for a certain period.

[Setting condition]

- When the SCL line state remains unchanged for the period specified by bits TMOH, TMOL, and TMOS in ICMR2 with the TMOE bit in ICFER set to 1 (timeout detection enabled) in master mode or in the slave specification state.

[Clearing conditions]

- When 0 is written to the TMOF bit after reading TMOF = 1
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

AL Flag (Arbitration Lost Flag)

This flag shows that bus mastership has been lost (loss in arbitration) due to a bus conflict or some other reason when a start condition is issued or an address and data are transmitted. The RIIC monitors the level on the SDA line during transmission and, if the level on the line does not match the value of the bit being output, sets the value of the AL bit to 1 to indicate that the bus is occupied by another device.

The RIIC can also set the flag to indicate the detection of loss of arbitration during NACK transmission in master mode or during data transmission in slave mode.

[Setting conditions]

<When master arbitration lost detection is enabled: ICFER.MALE = 1>

- When the internal SDA output state does not match the SDA line level at the rising edge of SCL clock except for the ACK period during data (including slave address) transmission in master transmit mode (when the SDA line is driven low while the internal SDA output is 1 (the SDA pin is in the high-impedance state))
- When a start condition is detected while the ST bit in ICCR2 is 1 (start condition issuance request) or the internal SDA output state does not match the SDA line level
- When the ST bit in ICCR2 is set to 1 (start condition issuance request) with the BBSY flag in ICCR2 set to 1.

<When NACK arbitration lost detection is enabled: ICFER.MALE = 1>

- When the internal SDA output state does not match the SDA line level at the rising edge of SCL clock in the ACK period during NACK transmission in receive mode

<When slave arbitration lost detection is enabled>

- When the internal SDA output state does not match the SDA line level at the rising edge of SCL clock except for the ACK period during data transmission in slave transmit mode

[Clearing conditions]

- When 0 is written to the AL bit after reading AL = 1
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

Table 24.5 Relationship between Arbitration Lost Generation Sources and Arbitration Lost Enable Functions

ICFER		ICSR2			
MALE	NALE	SALE	AL	Error	Arbitration Lost Generation Source
1	*	*	1	Start condition issuance error	When internal SDA output state does not match SDA line level when a start condition is detected while the ST bit in ICCR2 is 1
					When ST in ICCR2 is set to 1 with BBSY in ICCR2 set to 1
			1	Transmit data mismatch	When transmit data (including slave address) does not match the bus state in master transmit mode
*	1	*	1	NACK transmission mismatch	When ACK is detected during transmission of NACK in master receive mode or slave receive mode
*	*	1	1	Transmit data mismatch	When transmit data does not match the bus state in slave transmit mode

* : Don't care

START Flag (Start Condition Detection)

[Setting condition]

- When a start condition (or a restart condition) is detected

[Clearing conditions]

- When 0 is written to the START bit after reading START = 1
- When a stop condition is detected
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

STOP Flag (Stop Condition Detection)

[Setting condition]

- When a stop condition is detected

[Clearing conditions]

- When 0 is written to the STOP bit after reading STOP = 1
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

NACKF Flag (NACK Detection)

[Setting condition]

- When acknowledge is not received (NACK is received) from the receive device in transmit mode with the NACKE bit in ICFER set to 1 (transfer suspension enabled)

[Clearing conditions]

- When 0 is written to the NACKF bit after reading NACKF = 1
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

Note: • When the NACKF flag is set to 1, the RIIC suspends data transmission/reception. Writing to ICDRT in transmit mode or reading from ICDRR in receive mode with the NACKF flag set to 1 does not enable data transmit/receive operation. To restart data transmission/reception, clear the NACKF flag to 0.

RDRF Flag (Receive Data Full)

[Setting conditions]

- When receive data has been transferred from ICDRS to ICDRR
- This flag is set to 1 at the rising edge of the eighth or ninth SCL clock cycle (selected by the RDRFS bit in ICMR3)
- When the received slave address matches after a start condition (or a restart condition) is detected with the TRS bit in ICCR2 cleared to 0

[Clearing conditions]

- When 0 is written to the RDRF bit after reading RDRF = 1
- When data is read from ICDRR
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

TEND Flag (Transmit End)

[Setting condition]

- At the rising edge of the ninth SCL clock cycle while the TDRE flag is 1

[Clearing conditions]

- When 0 is written to the TEND bit after reading TEND = 1
- When data is written to ICDRT
- When a stop condition is detected
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

TDRE Flag (Transmit Data Empty)

[Setting conditions]

- When data has been transferred from ICDRT to ICDRS and ICDRT becomes empty
- When the TRS bit in ICCR2 is set to 1
  a. When the MST bit in ICCR2 is set to 1 after a start condition (or a restart condition) is detected
  b. When the RIIC enters transmit mode from receive mode
  c. When 1 is written to while the ICMR1.MTWP bit is 1
- When the received slave address matches while the TRS bit is 1

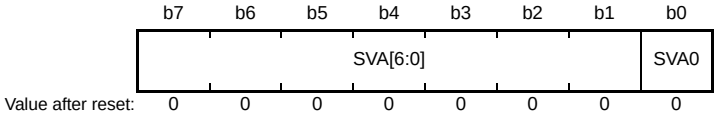
[Clearing conditions]

- When data is written to ICDRT
- When the TRS bit in ICCR2 is cleared to 0
  a. When a stop condition is detected
  b. When the RIIC enters receive mode from transmit mode
  c. When 0 is written to while the ICMR1.MTWP bit is 1
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

Note: • When the NACKF flag is set to 1 while the NACKE bit in ICFER is 1, the RIIC suspends data transmission/reception. Here, if the TDRE flag is 0 (next transmit data has been written), data is transferred to the ICDRS register and the ICDRT register becomes empty at the rising edge of the ninth clock cycle, but the TDRE flag is not set to 1.

24.2.11 Slave Address Register Ly (SARLy) (y = 0 to 2)

Address: SARL0 0008 830Ah
SARL1 0008 830Ch
SARL2 0008 830Eh



Bit	Symbol	Bit Name	Description	R/W
b0	SVA0	10-Bit Address LSB	The least significant bit (LSB) of a 10-bit slave address is set • When the FS bit in SARUy is 0 (7-bit address format), this bit is invalid • When the FS bit in SARUy is 1 (10-bit address format), this bit is the LSB of the lower 8-bit address (combined with the SVA[6:0] bits) of a 10-bit slave address	R/W
b7 to b1	SVA[6:0]	7-Bit Address/10-Bit Address Lower Bits	A slave address is set • When the FS bit in SARUy is 0 (7-bit address format), these bits form a 7-bit slave address • When the FS bit in SARUy is 1 (10-bit address format), these bits form the lower 8-bit address (combined with the SVA0 bit) of a 10-bit slave address	R/W

SARLy sets slave address y (7-bit address or lower eight bits of 10-bit address).

SVA0 Bit (10-Bit Address LSB)

When the 10-bit address format is selected (SARUy.FS = 1), this bit functions as the LSB of a 10-bit address and forms the lower eight bits of a 10-bit address in combination with the SVA[6:0] bits.
When the SARyE bit in ICSER is set to 1 (SARLy and SARUy enabled) and the SARUy.FS bit is 1, this bit is valid. While the SARUy.FS bit or SARyE bit is 0, the setting of this bit is ignored.

SVA[6:0] Bits (7-Bit Address/10-Bit Address Lower Bits)

When the 7-bit address format is selected (SARUy.FS = 0), these bits function as a 7-bit address. When the 10-bit address format is selected (SARUy.FS = 1), these bits function as the lower eight bits of a 10-bit address in combination with the SVA0 bit.
While the SARyE bit in ICSER is 0, the setting of these bits is ignored.

24.2.12 Slave Address Register Uy (SARUy) (y = 0 to 2)

Address: SARL0 0008 830Ah
SARL1 0008 830Ch
SARL2 0008 830Eh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	SVA[1:0]		FS
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	FS	7-Bit/10-Bit Address Format Selection	0: The 7-bit address format is selected 1: The 10-bit address format is selected	R/W
b2, b1	SVA[1:0]	10-Bit Address Upper Bits	A slave address is set • When the SARUy.FS bit is 0 (7-bit address format), these bits are invalid • When the SARUy.FS bit is 1 (10-bit address format), these bits form the upper two bits of a 10-bit slave address	R/W
b7 to b3	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

SARUy selects 7-bit address format or 10-bit address format and sets the upper bits of a 10-bit slave address.

FS Bit (7-Bit/10-Bit Address Format Selection)

This bit is used to select 7-bit address or 10-bit address for slave address y (in SARLy and SARUy).
When the SARyE bit in ICSER is set to 1 (SARLy and SARUy enabled) and the SARUy.FS bit is 0, the 7-bit address format is selected for slave address y, the SVA[6:0] setting in SARLy is valid, and the settings of the SVA[1:0] bits and the SVA0 bit in SARLy are ignored.
When the SARyE bit in ICSER is set to 1 (SARLy and SARUy enabled) and the SARUy.FS bit is 1, the 10-bit address format is selected for slave address m and the settings of the SVA[1:0] bits and SARLy are valid.
While the SARyE bit in ICSER is 0 (SARLy and SARUy disabled), the setting of the SARUy.FS bit is invalid.

SVA[1:0] Bits (10-Bit Address Upper Bits)

When the 10-bit address format is selected (FS = 1), these bits function as the upper two bits of a 10-bit address.
When the SARyE bit in ICSER is set to 1 (SARLy and SARUy enabled) and the SARUy.FS bit is 1, these bits are valid.
While the SARUy.FS bit or SARyE bit is 0, the setting of these bits is ignored.

24.2.13 I2C Bus Bit Rate Low-Level Register (ICBRL)

Address: ICBRL 0008 8310h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	BRL[4:0]				
Value after reset:	1	1	1	1	1	1	1	1

Bit	Symbol	Bit Name	Description	R/W
b4 to b0	BRL[4:0]	Bit Rate Low-Level Period	Low-level period of SCL clock	R/W
b7 to b5	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W

ICBRL is a 5-bit register to set the low-level period of SCL clock. It also works to generate the data setup time for automatic SCL low-hold operation (see section 24.8, Function to Automatically Hold SCL Clock Low; when the RIIC is used only in slave mode, this register needs to be set to a value longer than the data setup time*1.
ICBRL counts the low-level period with the internal reference clock source (IICϕ) specified by the CKS[2:0] bits in ICMR1.

Note 1. Data setup time (tSU: DAT)
250 ns (up to 100 kbps: standard mode [Sm])
100 ns (up to 400 kbps: fast mode [fm])

24.2.14 I2C Bus Bit Rate High-Level Register (ICBRH)

Address: 0008 8311h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	BRH[4:0]				
Value after reset:	1	1	1	1	1	1	1	1

Bit	Symbol	Bit Name	Description	R/W
b4 to b0	BRH[4:0]	Bit Rate High-Level Period	High-level period of SCL clock	R/W
b7 to b5	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W

ICBRH is a 5-bit register to set the high-level period of SCL clock. ICBRH is valid in master mode. If the RIIC is used only in slave mode, this register need not to set the high-level period.
ICBRH counts the high-level period with the internal reference clock source (IICϕ) specified by the CKS[2:0] bits in ICMR1.

The I2C transfer rate and the SCL clock duty are calculated using the following expression.
Transfer rate = 1 / {[(ICBRH + 1) + (ICBRL + 1)] / IICϕ*1 + SCL line rising time [tr] + SCL line falling time [tf]}

Duty cycle = {SCL line rising time [tr]*2 + (ICBRH + 1) / IICϕ} / {SCL line falling time [tf]*2 + (ICBRL+1) / IICϕ}

Note 1. IICϕ = PCLK × 10^6 × Division ratio
Note 2. 2.The SCL line rising time [tr] and SCL line falling time [tf] depend on the total bus line capacitance [Cb] and the pull-up resistor [Rp]. For details, see the I2C bus standard from NXP Semiconductors.

Table 24.6 shows examples of ICBRH/ICBRL settings.

Table 24.6 Examples of ICBRH/ICBRL Settings for Transfer Rate

Transfer Rate (kbps)	Operating Frequency PCLK (MHz)								
	8			10			12.5		
	CKS [2:0]	ICBRH	ICBRL	CKS [2:0]	ICBRH	ICBRL	CKS [2:0]	ICBRH	ICBRL
10	100b	22 (F6h)	25 (F9h)	101b	13 (EDh)	15 (EFh)	101b	16 (F0h)	20 (F4h)
50	010b	16 (F0h)	19 (F3h)	010b	21 (F5h)	24 (F8h)	011b	12 (ECh)	15 (EFh)
100	001b	15 (EFh)	18 (F2h)	001b	19 (F3h)	23 (F7h)	001b	24 (F8h)	29 (FDh)
400	000b	4 (E4h)	10 (EAh)	000b	5 (E5h)	12 (ECh)	000b	7 (E7h)	16 (F0h)

Transfer Rate (kbps)	Operating Frequency PCLK (MHz)								
	16			20			25		
	CKS [2:0]	ICBRH	ICBRL	CKS [2:0]	ICBRH	ICBRL	CKS [2:0]	ICBRH	ICBRL
10	101b	22 (F6h)	25 (F9h)	110b	13 (EDh)	15 (EFh)	110b	16 (F0h)	20 (F4h)
50	011b	16 (F0h)	19 (F3h)	011b	21 (F5h)	24 (F8h)	100b	12 (ECh)	15 (EFh)
100	010b	15 (EFh)	18 (F2h)	010b	19 (F3h)	23 (F7h)	010b	24 (F8h)	29 (FDh)
400	000b	9 (E9h)	20 (F4h)	000b	11 (EBh)	25 (F9h)	001b	7 (E7h)	16 (F0h)

Transfer Rate (kbps)	Operating Frequency PCLK (MHz)								
	30			33			50		
	CKS [2:0]	ICBRH	ICBRL	CKS [2:0]	ICBRH	ICBRL	CKS [2:0]	ICBRH	ICBRL
10	110b	20 (F4h)	24 (F8h)	110b	22 (F6h)	26 (FAh)	111b	16 (F0h)	20 (F4h)
50	100b	15 (EFh)	18 (F2h)	100b	17 (F1h)	20 (F4h)	100b	26 (FAh)	31 (FFh)
100	010b	2 (E2h)	3 (E3h)	011b	16 (F0h)	19 (F3h)	011b	24 (F8h)	29 (FDh)
400	001b	8 (E8h)	19 (F3h)	001b	9 (E9h)	21 (F5h)	010b	7 (E7h)	16 (F0h)

Note: • ICBRH/ICBRL settings in these tables are calculated using the following values:
SCL line rising time (tr): 100 kbps or less, [Sm]: 1000 ns, 400 kbps or less, [Fm]: 300 ns
SCL line falling time (tf): 400 kbps or less, [Sm/Fm]: 300 ns
For the specified values of SCL line rising time (tr) and SCL line falling time (tf), see the I^2C bus standard from NXP Semiconductors.

24.2.15 I2C Bus Transmit Data Register (ICDRT)

Address: 0008 8312h

	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	1	1	1	1	1	1	1	1

ICDRT is an 8-bit readable/writable register that stores transmit data. When ICDRT detects a space in the I2C bus shift register (ICDRS), it transfers the transmit data that has been written to ICDRT to ICDRS and starts transmitting data in transmit mode.
The double-buffer structure of ICDRT and ICDRS allows continuous transmit operation if the next transmit data has been written to ICDRT while the ICDRS data is being transmitted.
ICDRT can always be read and written. Write transmit data to ICDRT once when a transmit data empty interrupt (ICTXI) request is generated.

24.2.16 I2C Bus Receive Data Register (ICDRR)

Address: 0008 8313h

	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	0	0	0	0	0	0	0	0

ICDRR is an 8-bit read-only register that stores receive data. When one byte of data has been received, the received data is transferred from the I2C bus shift register (ICDRS) to ICDRR to enable the next data to be received.
The double-buffer structure of ICDRS and ICDRR allows continuous receive operation if the received data has been read from ICDRR while ICDRS is receiving data.
ICDRR cannot be written. Read data from ICDRR once when a receive data full interrupt (ICRXI) request is generated.
If ICDRR receives the next receive data before the current data is read from ICDRR (while the RDRF flag in ICSR2 is 1), the RIIC automatically holds the SCL clock low one cycle before the RDRF flag is set to 1 next.

24.2.17 I2C Bus Shift Register (ICDRS)

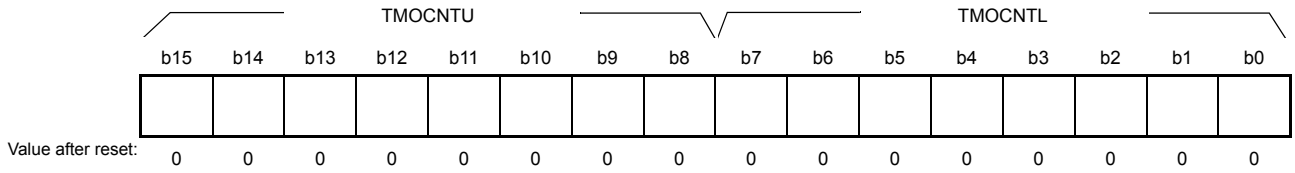
	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	—	—	—	—	—	—	—	—

ICDRS is an 8-bit shift register to transmit and receive data.
During transmission, transmit data is transferred from ICDRT to ICDRS and is sent from the SDA pin. During reception, data is transferred from ICDRS to ICDRR after one byte of data has been received.
ICDRS cannot be accessed directly.

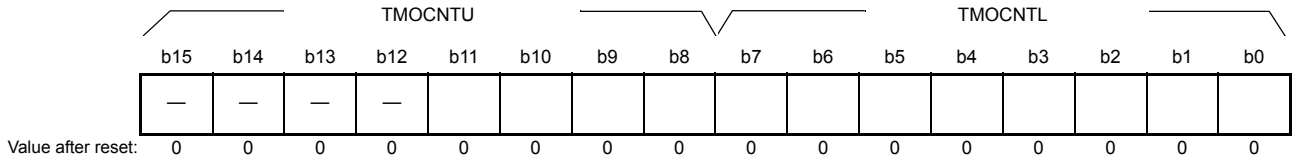
24.2.18 Timeout internal counter (TMOCNT)

Address: TMOCNTL 0008 830Ah*1, RIIC1.TMOCNTU 0008 830Bh*1

- TMOS = 0 (Long mode)



- TMOS = 1 (Short mode)



Note 1. Same address with ones of the slave address registers, SARL0,SARU0. Care should be taken.

Bit	Symbol	Bit Name	Description	R/W
b15 to b8	TMOCNTU	Timeout internal counter	Timeout internal counter high-order*1	W*2
b7 to b0	TMOCNTU		Timeout internal counter low-order	

Note 1. With TMOS = 1 (Short mode), b15 to b12 are reserved bits. They are writable. however value written is disabled.
Note 2. Value in timeout internal counter cannot be read. When value is read, the read value is FFFFh

Timeout internal counter (TMOCNTL/TMOCNTU) is initialized (0000h) after a reset, while ICCR1.IICRST=1 or ICFER.TMOE = 1 and PCLK/1 is selected with ICMR1.CKS[2:0] = 000b setting, and when counter clear conditions specified by TMOH/TMOL of ICMR2 (SCL rising edge/falling edge detection) are satisfied.

24.3 Operation

24.3.1 Communication Data Format

The I2C bus format consists of 8-bit data and 1-bit acknowledge. The frame following a start condition or restart condition is an address frame used to specify a slave device with which the master device communicates. The specified slave is valid until a new slave is specified or a stop condition is issued.
Figure 24.3 shows the I2C bus format, and Figure 24.4 shows the I2C bus timing.

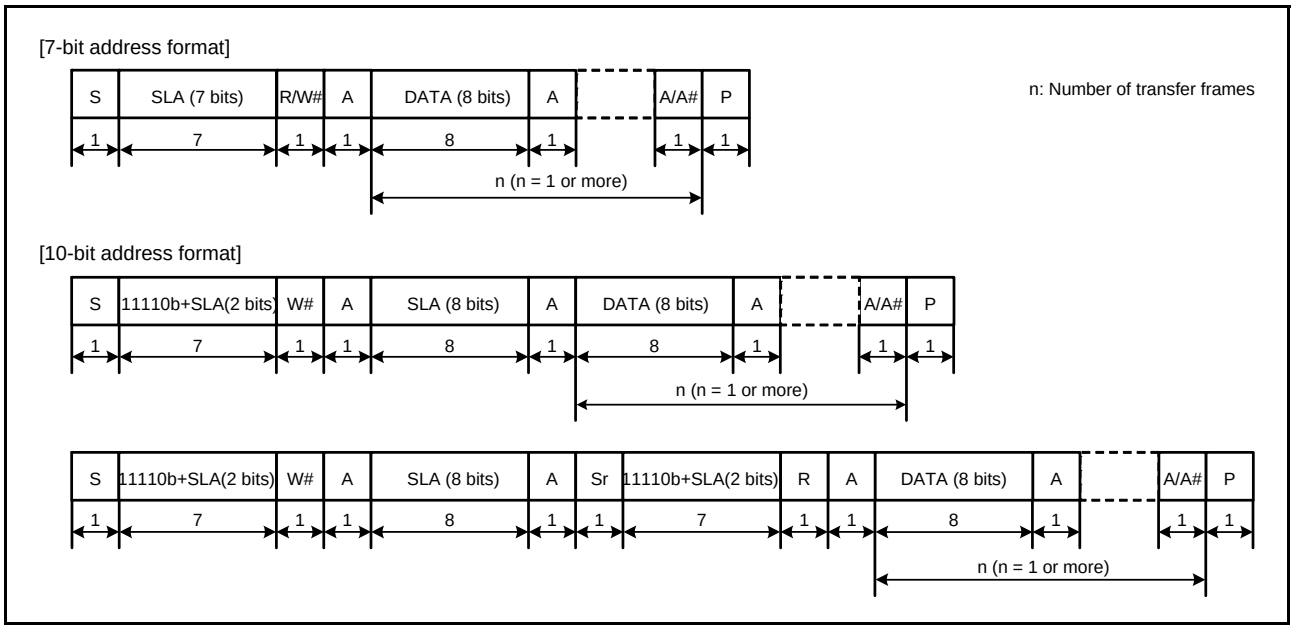


Figure 24.3 I2C Bus Format

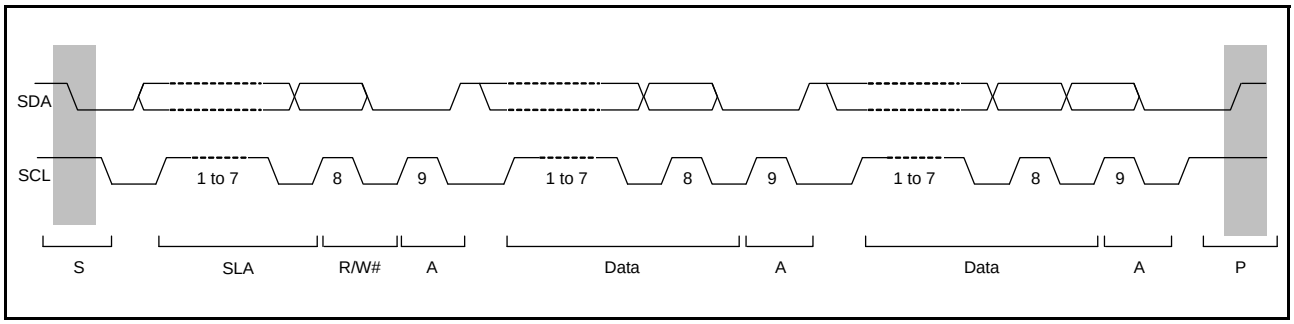
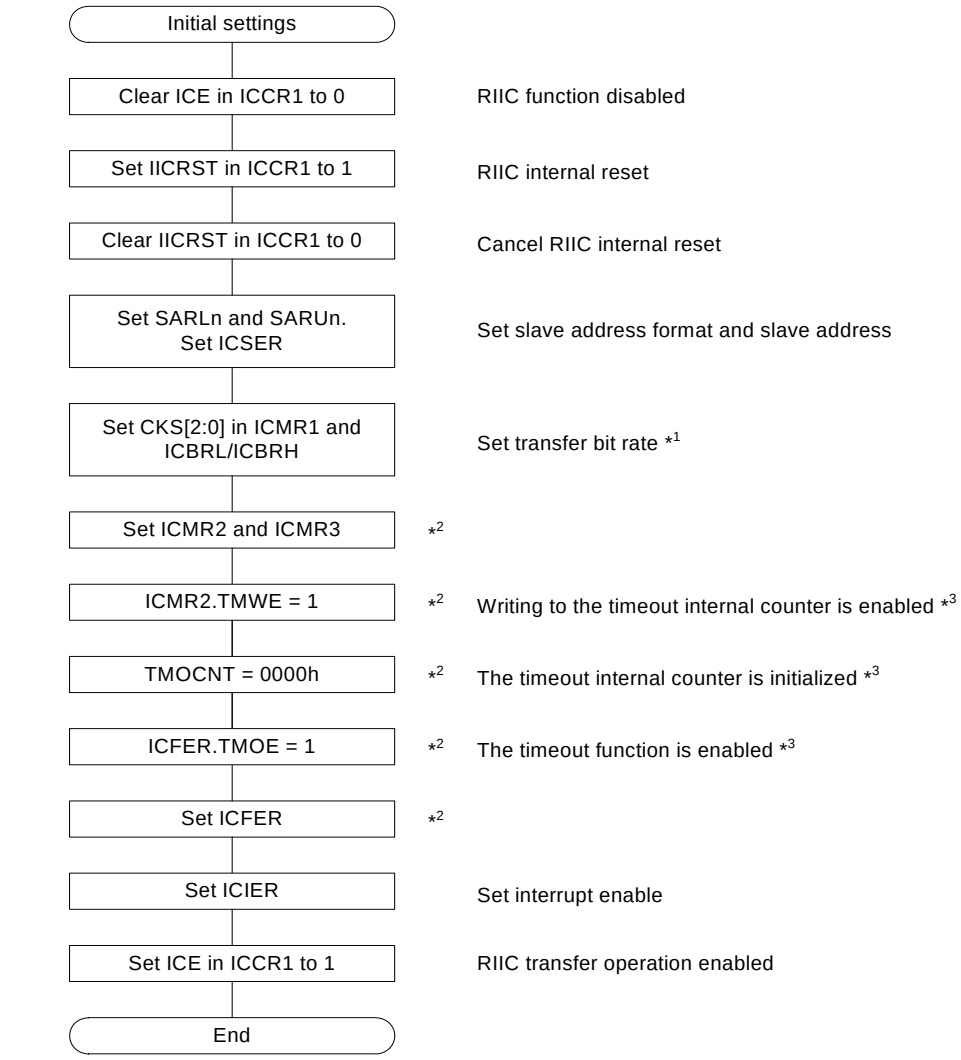


Figure 24.4 I2C Bus Timing (SLA = 7 Bits)

S: Start condition. The master device drives the SDA line low from high level while the SCL line is at a high level.
SLA: Slave address, by which the master device selects a slave device.
R/W#: Indicates the direction of data transfer: from the slave device to the master device when R/W is 1, or from the master device to the slave device when R/W is 0.
A: Acknowledge. The receive device drives the SDA line low. (In master transmit mode, the slave device returns acknowledge. In master receive mode, the master device returns acknowledge.)
Sr: Restart condition. The master device drives the SDA line low from the high level after the setup time has elapsed with the SCL line at the high level.
DATA: Transmitted or received data
P: Stop condition. The master device drives the SDA line high from low level while the SCL line is at a high level.

24.3.2 Initial Settings

Before starting data transmission and reception, initialize the RIIC according to the procedure in Figure 24.5.



[Legend] n = 0 to 2

Notes: 1. When the RIIC is used only in slave mode, set the ICBRL register to a value longer than the data setup time.
2. Set these registers as necessary.
3. Those procedures need to be added only when using timeout function. Not needed when not using timeout function.

Figure 24.5 Example of RIIC Initialization Flow

24.3.3 Master Transmitter Operation

In master transmitter operation, the RIIC outputs the SCL (clock) and transmitted data signals as the master device, and the slave device returns acknowledgements. Figure 24.6 shows an example of usage of master transmission and Figure 24.7 to Figure 24.9 show the timing of operations in master transmission.
The following describes the procedure and operations for master transmission.

1. Set the IICRST bit in ICCR1 to 1 (internal reset) and then clear the IICRST bit to 0 (canceling reset) with the ICE bit in ICCR1 cleared to 0 (disabling the interface). This initializes the internal state and the various flags of ICSR1. After that, set registers SARLy, SARUy, ICSER, ICMR1, ICBRH, and ICBRL (y = 0 to 2), and set the other registers as necessary (for initial settings of the RIIC, see Figure 24.5). When the necessary register settings have been completed, set the ICE bit to 1 (to enable transfer). This step is not necessary if initialization of the RIIC has already been completed.
2. Read the BBSY flag in ICCR2 to check that the bus is open, and then set the ST bit in ICCR2 to 1 (start condition issuance request). Upon receiving the request, the RIIC issues a start condition. At the same time, the BBSY flag and the START flag in ICSR2 are automatically set to 1 and the ST bit is automatically cleared to 0. At this time, if the start condition is detected and the internal levels for the SDA output state and the levels on the SDA line have matched while the ST bit is 1, the RIIC recognizes that issuing of the start condition as requested by the ST bit has been successfully completed, and the MST and TRS bits in ICCR2 are automatically set to 1, placing the RIIC in master transmitter mode. The TDRE flag in ICSR2 is also automatically set to 1 in response to setting of the TRS bit to 1.
3. Check that the TDRE flag in ICSR2 is 1, and then write the value for transmission (the slave address and the R/W# bit) to ICDRT. Once the data for transmission are written to ICDRT, the TDRE flag is automatically cleared to 0, the data are transferred from ICDRT to ICDRS, and the TDRE flag is again set to 1. After the byte containing the slave address and R/W# bit has been transmitted, the value of the TRS bit is automatically updated to select master transmitter or master receiver mode in accord with the value of the transmitted R/W# bit. If the value of the R/W# bit was 0, the RIIC continues in master transmitter mode.
   Since the ICSR2.NACKF flag being 1 at this time indicates that no slave device recognized the address or there was an error in communications, write 1 to the ICCR2.SP bit to issue a stop condition.
   For data transmission with an address in the 10-bit format, start by writing 1111 0b, the two higher-order bits of the slave address, and W to ICDRT as the first address transmission. Then, as the second address transmission, write the eight lower-order bits of the slave address to ICDRT.
4. After confirming that the TDRE flag in ICSR2 is 1, write the data for transmission to the ICDRT register. The RIIC automatically holds the SCL line low until the data for transmission are ready or a stop condition is issued.
5. After all bytes of data for transmission have been written to the ICDRT register, wait until the value of the TEND flag in ICSR2 returns to 1, and then set the SP bit in ICCR2 to 1 (stop condition issuance request). Upon receiving a stop condition issuance request, the RIIC issues the stop condition.
6. Upon detecting the stop condition, the RIIC automatically clears the MST and TRS bits in ICCR2 to 00b and enters slave receiver mode. Furthermore, it automatically clears the TDRE and TEND flags to 0, and sets the STOP flag in ICSR2 to 1.
7. After checking that the ICSR2.STOP flag is 1, clear the ICSR2.NACKF and STOP flags to 0 for the next transfer operation.

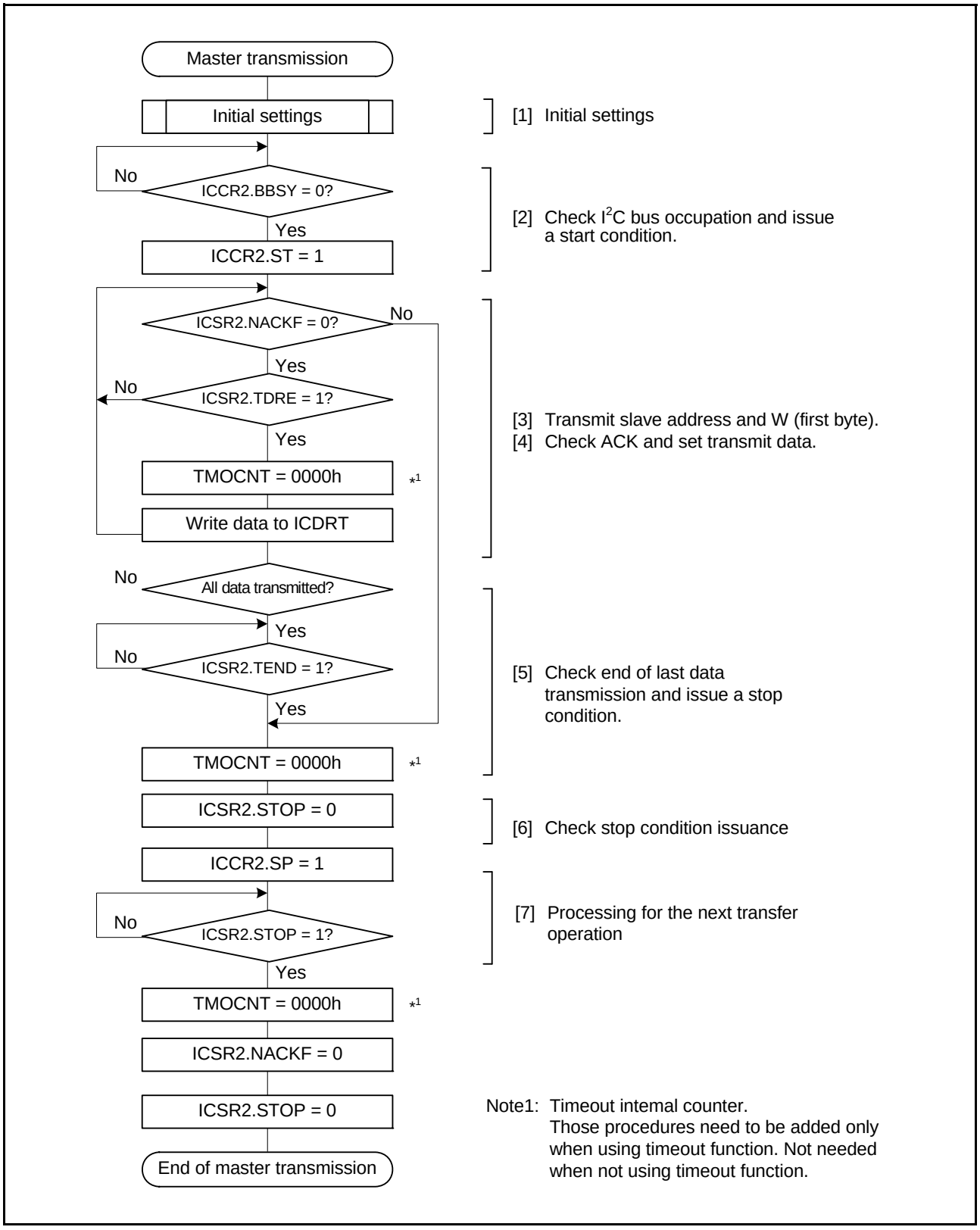


Figure 24.6 Example of Master Transmission Flowchart

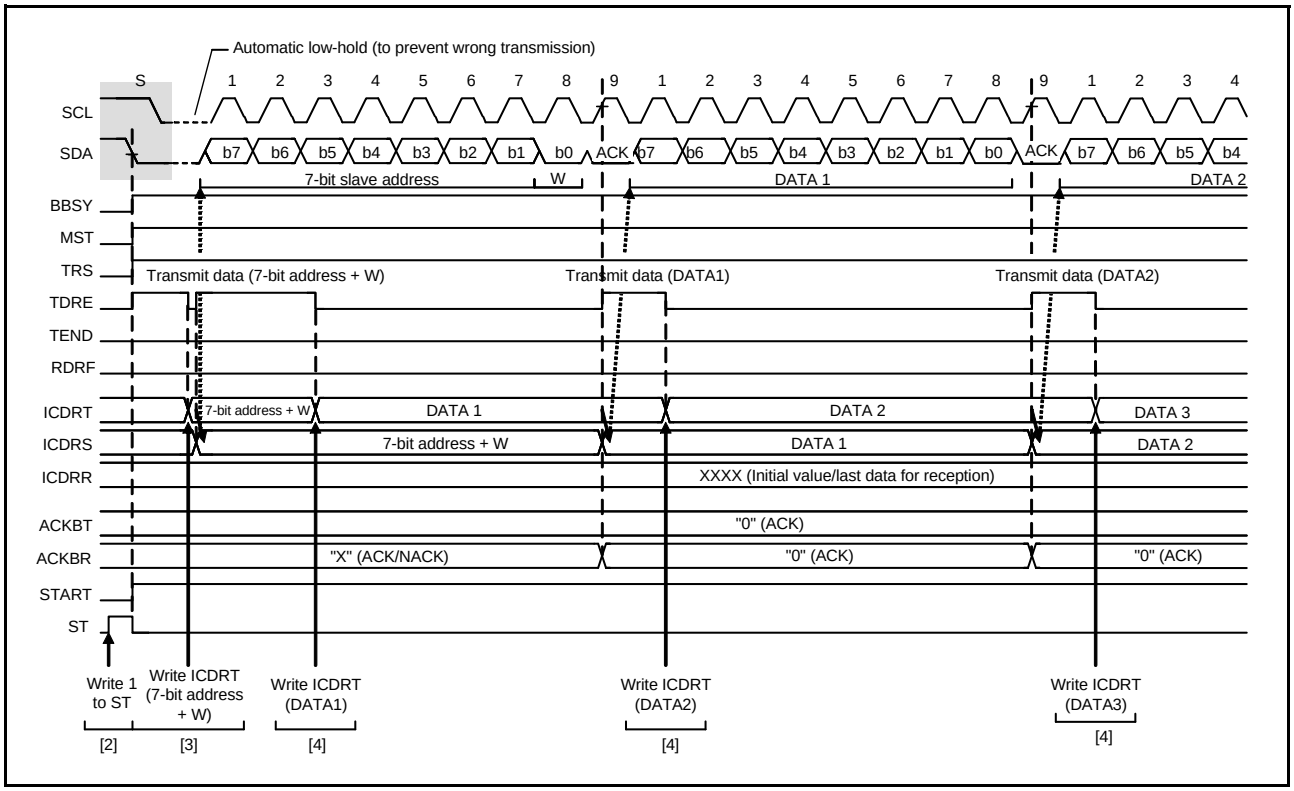


Figure 24.7 Master Transmit Operation Timing (1) (7-Bit Address Format)

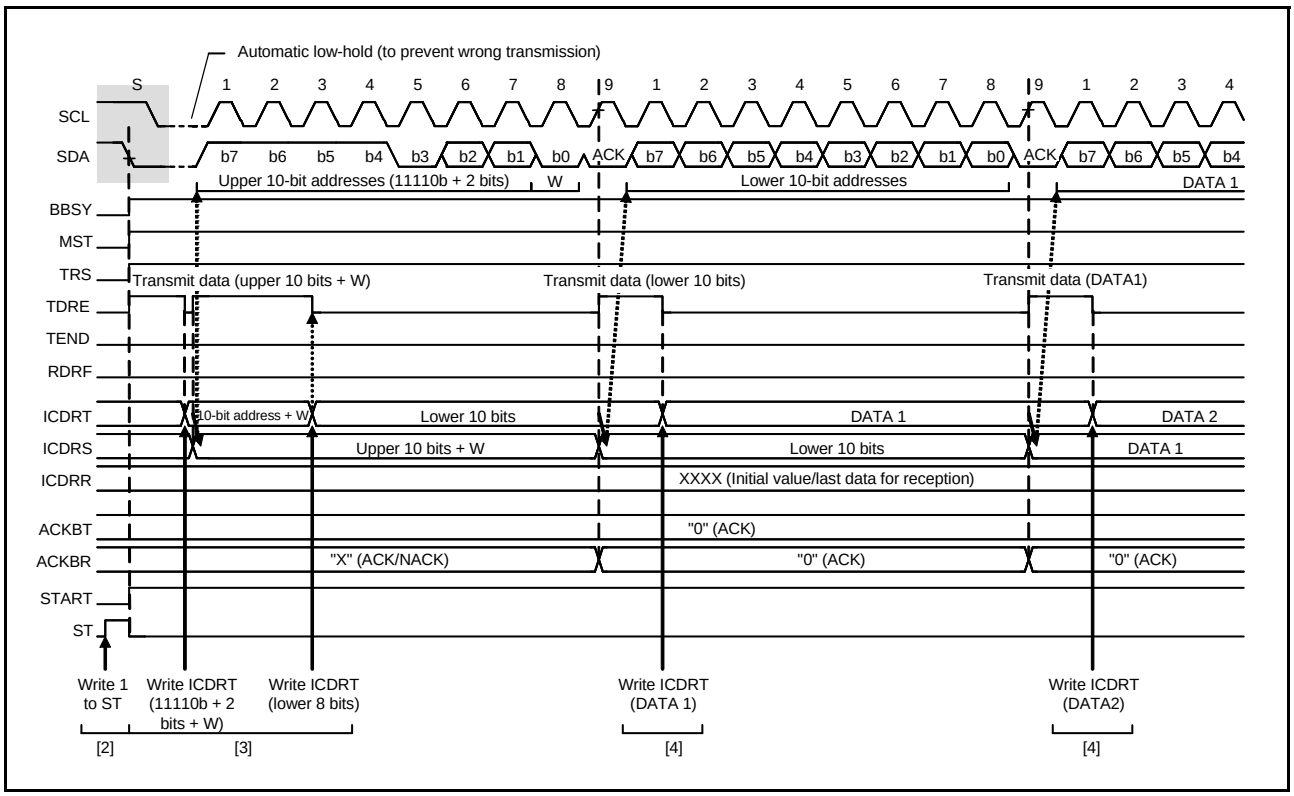


Figure 24.8 Master Transmit Operation Timing (2) (10-Bit Address Format)

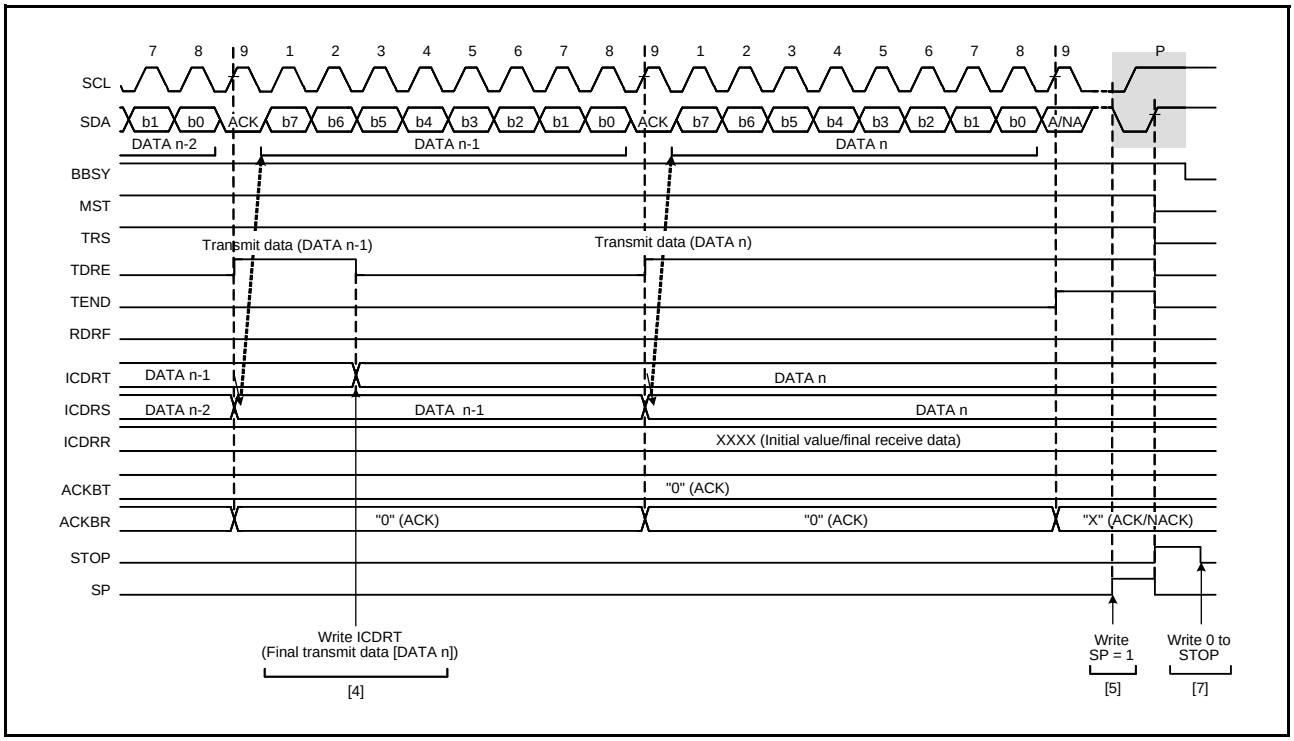


Figure 24.9 Master Transmit Operation Timing (3)

24.3.4 Master Receiver Operation

In master receiver operation, the RIIC as a master device outputs the SCL (clock) signal, receives data from the slave device, and returns acknowledgements. Since the RIIC must start by sending a slave address to the corresponding slave device, this part of the procedure is performed in master transmitter mode, but the subsequent steps are in master receiver mode.

Figure 24.10 shows an example of usage of master reception and Figure 24.11 and Figure 24.13 show the timing of operations in master reception.

The following describes the procedure and operations for master reception.

1. Set the IICRST bit in ICCR1 to 1 (internal reset) and then clear the IICRST bit to 0 (canceling reset) with the ICE bit in ICCR1 cleared to 0 (disabling the interface). This initializes the internal state and the various flags of ICSR1. After that, set registers SARLy, SARUy, ICSER, ICMR1, ICBRH, and ICBRL (y = 0 to 2), and set the other registers as necessary (for initial settings of the RIIC, see Figure 24.5). When the necessary register settings have been completed, set the ICE bit to 1 (to enable transfer). This step is not necessary if initialization of the RIIC has already been completed.
2. Read the BBSY flag in ICCR2 to check that the bus is open, and then set the ST bit in ICCR2 to 1 (start condition issuance request). Upon receiving the request, the RIIC issues a start condition. When the RIIC detects the start condition, the BBSY flag and the START flag in ICSR2 are automatically set to 1 and the ST bit is automatically cleared to 0. At this time, if the start condition is detected and the levels for the SDA output and the levels on the SDA line have matched while the ST bit is 1, the RIIC recognizes that issuing of the start condition as requested by the ST bit has been successfully completed, and the MST and TRS bits in ICCR2 are automatically set to 1, placing the RIIC in master transmitter mode. The TDRE flag in ICSR2 is also automatically set to 1 in response to setting of the TRS bit to 1.
3. Check that the TDRE flag in ICSR2 is 1, and then write the value for transmission (the first byte indicates the slave address and value of the R/W# bit) to ICDRT. Once the data for transmission are written to ICDRT, the TDRE flag is automatically cleared to 0, the data are transferred from ICDRT to ICDRS, and the TDRE flag is again set to 1. Once the byte containing the slave address and R/W# bit has been transmitted, the value of the ICCR2.TRS bit is automatically updated to select master transmitter or master receiver mode in accord with the value of the transmitted R/W# bit. If the value of the R/W# bit was 1, the TRS bit is cleared to 0 on the rising edge of the ninth cycle of SCL (the clock signal), placing the RIIC in master receiver mode. At this time, the TDRE flag is automatically cleared to 0 and the ICSR2.RDRF flag is automatically set to 1.
   Since the ICSR2.NACKF flag being 1 at this time indicates that no slave device recognized the address or there was an error in communications, write 1 to the ICCR2.SP bit to issue a stop condition.
   For master reception from a device with a 10-bit address, start by using master transmission to issue the 10-bit address, and then issue a restart condition. After that, transmitting 1111 0b, the two higher-order bits of the slave address, and the R bit places the RIIC in master receiver mode.
4. Dummy read ICDRR after confirming that the RDRF flag in ICSR2 is 1; this makes the RIIC start output of the SCL (clock) signal and start data reception.
5. After one byte of data has been received, the RDRF flag in ICSR2 is set to 1 on the rising edge of the eighth or ninth cycle of SCL clock (the clock signal) as selected by the RDRFS bit in ICMR3. Reading out ICDRR at this time will produce the received data, and the RDRF flag is automatically cleared to 0 at the same time. Furthermore, the value of the acknowledgement field received during the ninth cycle of SCL clock is returned as the value set in the ACKBT bit of ICMR3. Furthermore, if the next byte to be received is the next to last byte, set the ICMR3.WAIT bit to 1 (for wait insertion) before reading the ICDRR (containing the second byte from last). As well as enabling NACK output even in the case of delays in processing to set the ICMR3.ACKBT bit to 1 (NACK) in step (6), due to other interrupts etc., this fixes the SCLn line to the low level on the rising edge of the ninth clock cycle in reception of the last byte, so the state is such that issuing a stop condition is possible.
6. When the ICMR3.RDRFS bit is 0 and the slave device must be notified that it is to end transfer for data reception after transfer of the next (final) byte, set the ACKBT bit in ICMR3 to 1 (NACK).

7. After reading out the byte before last from the ICDRR register, if the value of the ICSR2.RDRF flag is confirmed to be 1, write 1 to the SP bit in ICCR2 (stop condition issuance request) and then read the last byte from ICDRR. When ICDRR is read, the RIIC is released from the wait state and issues the stop condition after low-level output in the ninth clock cycle is completed or the SCL line is released from the low-hold state.
8. Upon detecting the stop condition, the RIIC automatically clears the MST and TRS bits in ICCR2 to "00b" and enters slave receiver mode. Furthermore, detection of the stop condition leads to setting of the STOP flag in ICSR2 to 1.
9. After checking that the ICSR2.STOP flag is 1, clear the ICSR2.NACKF and STOP flags to 0 for the next transfer operation.

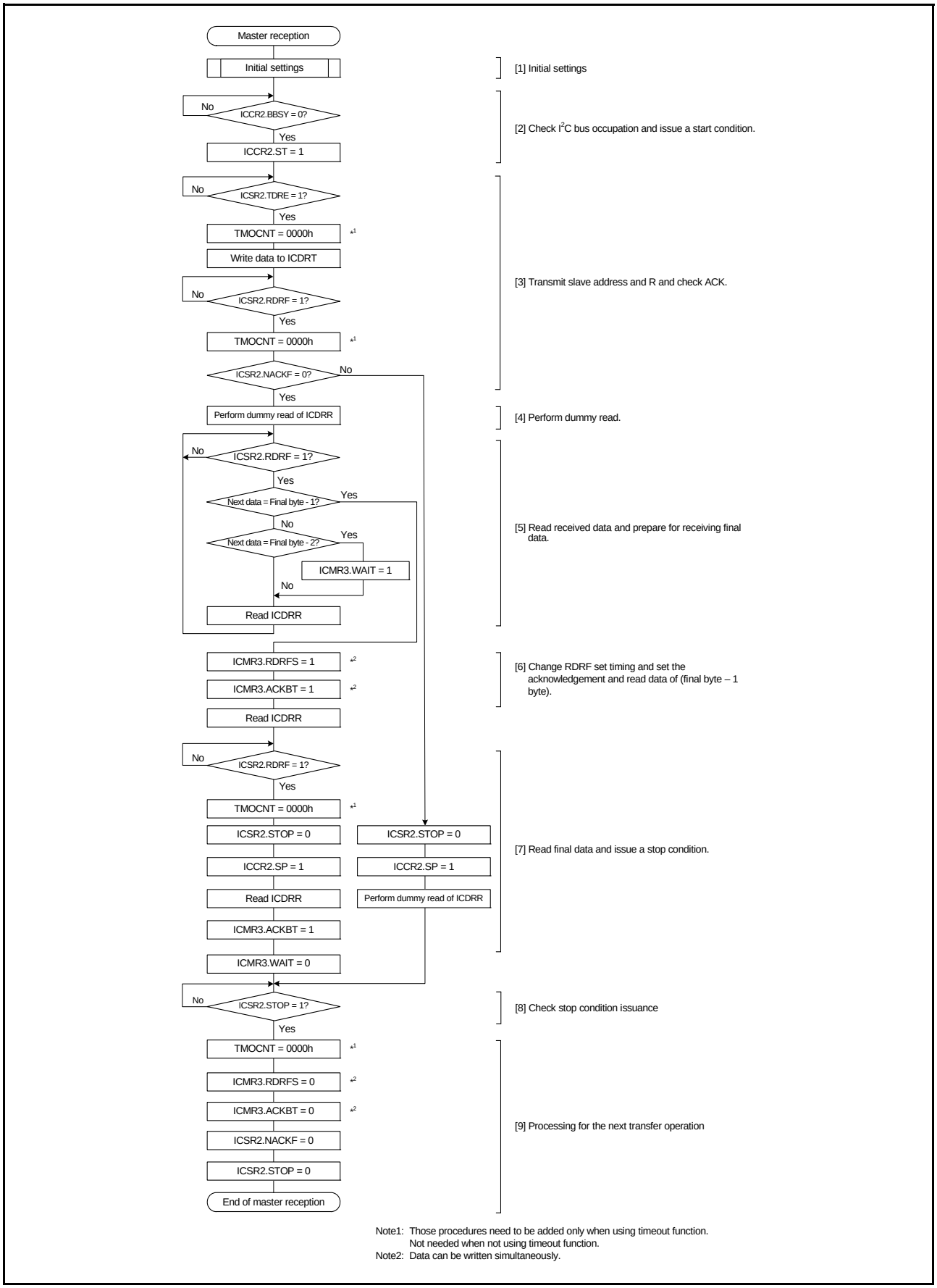


Figure 24.10 Example of Master Reception Flowchart (7-Bit Address Format)

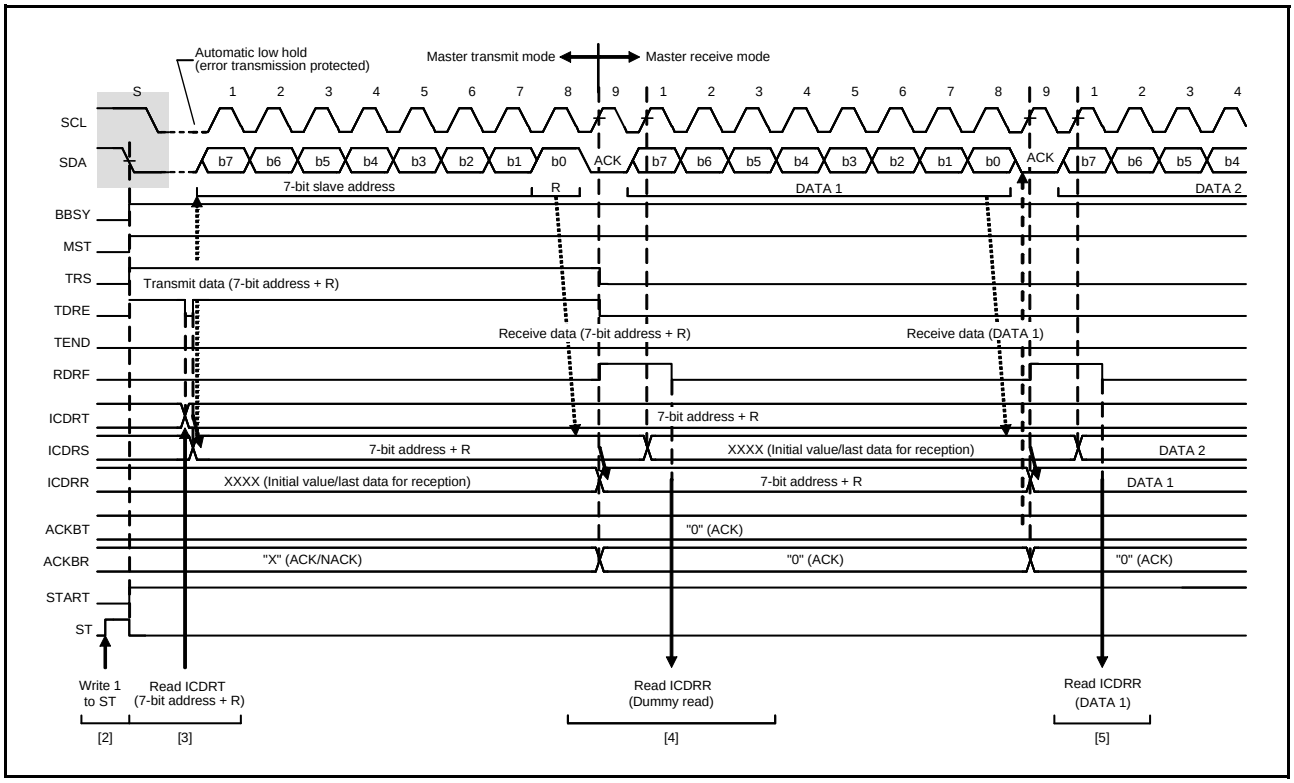


Figure 24.11 Master Receive Operation Timing (1) (7-Bit Address Format, when RDRFS=0)

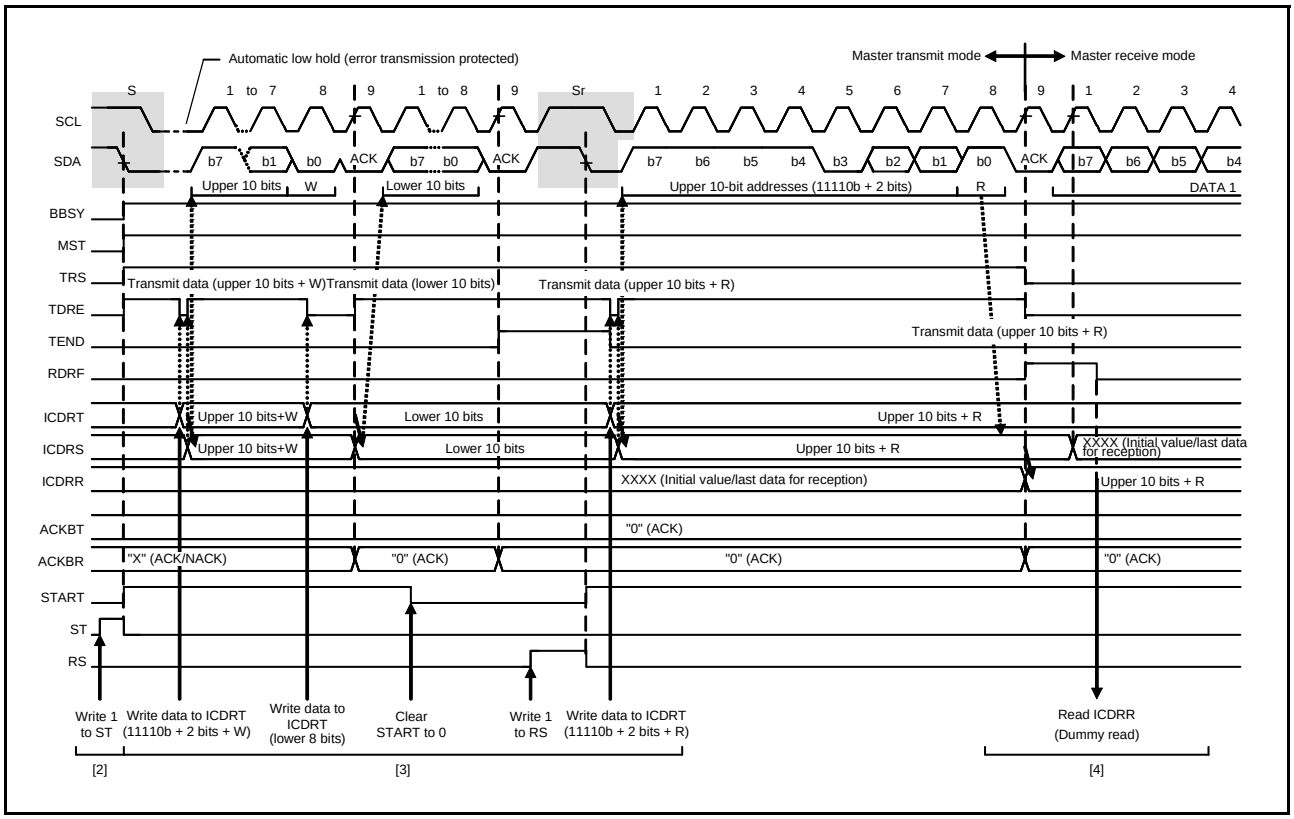


Figure 24.12 Master Receive Operation Timing (2) (10-Bit Address Format, when RDRFS=0)

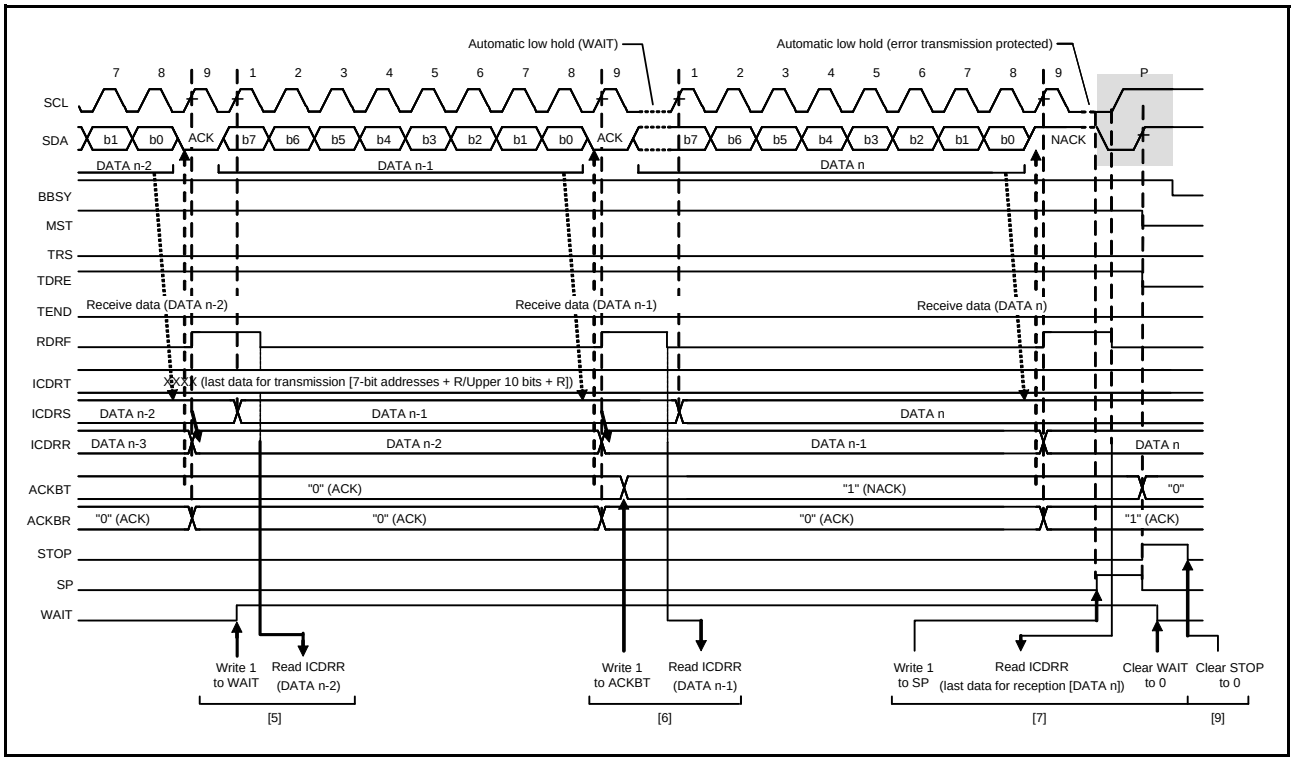


Figure 24.13 Master Receive Operation Timing (3) (when RDRFS=0)

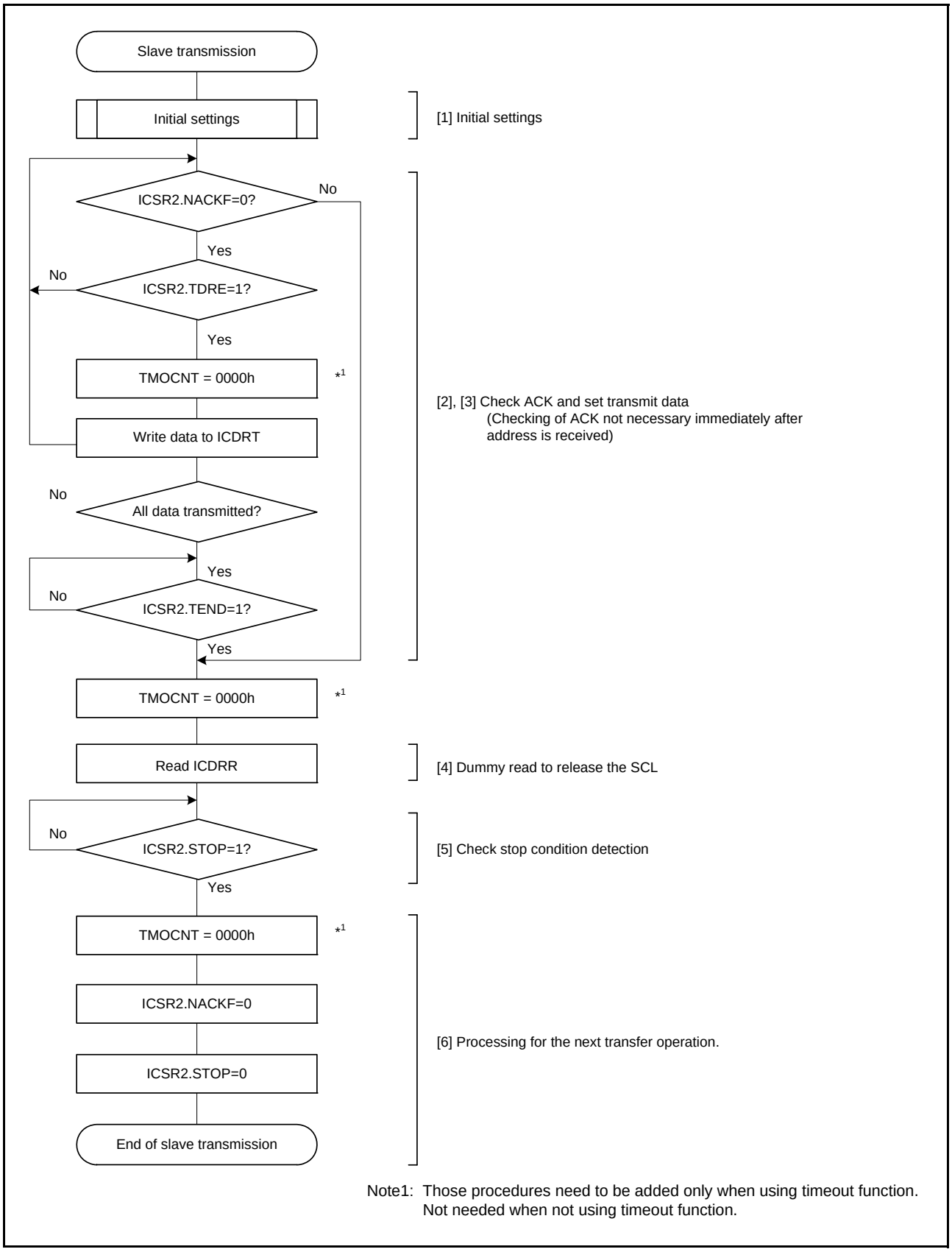
24.3.5 Slave Transmitter Operation

In slave transmitter operation, the master device outputs the SCL (clock) signal, the RIIC transmits data as a slave device, and the master device returns acknowledgements.

Figure 24.14 shows an example of usage of slave transmission and Figure 24.15 and Figure 24.16 show the timing of operations in slave transmission.

The following describes the procedure and operations for slave transmission.

1. Follow the procedure in Figure 24.5 to make initial settings for the RIIC. This step is not necessary if initialization of the RIIC has already been completed. After initial settings, the RIIC will stay in the standby state until it receives a slave address that it matches.
2. After receiving a matching slave address, the RIIC sets one of the corresponding bits ICSR1.HOA, GCA, and AASy (y = 0 to 2) to 1 on the rising edge of the ninth cycle of SCL clock (the clock signal) and outputs the value set in the ICMR3.ACKBT bit to the acknowledge bit on the ninth cycle of SCL clock. If the value of the R/W# bit that was also received at this time is 1, the RIIC automatically places itself in slave transmitter mode by setting both the TRS bit and the TDRE flag in ICSR2 to 1.
3. After the ICSR2.TEND flag is confirmed to be 1, write the data for transmission to the ICDRT register. At this time, if the RIIC receives no acknowledge from the master device (receives an NACK signal) while the ICFER.NACKE bit is 1, the RIIC suspends transfer of the next data.
4. Wait unit the ICSR2.TEND flag is set to 1 while the ICSR2.TDRE flag is 1, after the ICSR2.NACKF flag is set to 1or the last byte for transmission is written to the ICDRT register. When the ICSR2.NACKF flag or the TEND flag is 1, the RIIC drives the SCL line low on the ninth falling edge of SCL clock.
5. When the ICSR2.NACKF flag or the ICSR2.TEND flag is 1, dummy read ICDRR to complete the processing. This releases the SCL line.
6. Upon detecting the stop condition, the RIIC automatically clears bits ICSR1.HOA, GCA, and AASy (y = 0 to 2), flags ICSR2.TDRE and TEND, and the ICCR2.TRS bit to 0, and enters slave receiver mode.
7. After checking that the ICSR2.STOP flag is 1, clear the ICSR2.NACKF and STOP flags to 0 for the next transfer operation.



Note1: Those procedures need to be added only when using timeout function. Not needed when not using timeout function.

Figure 24.14 Example of Slave Transmission Flowchart

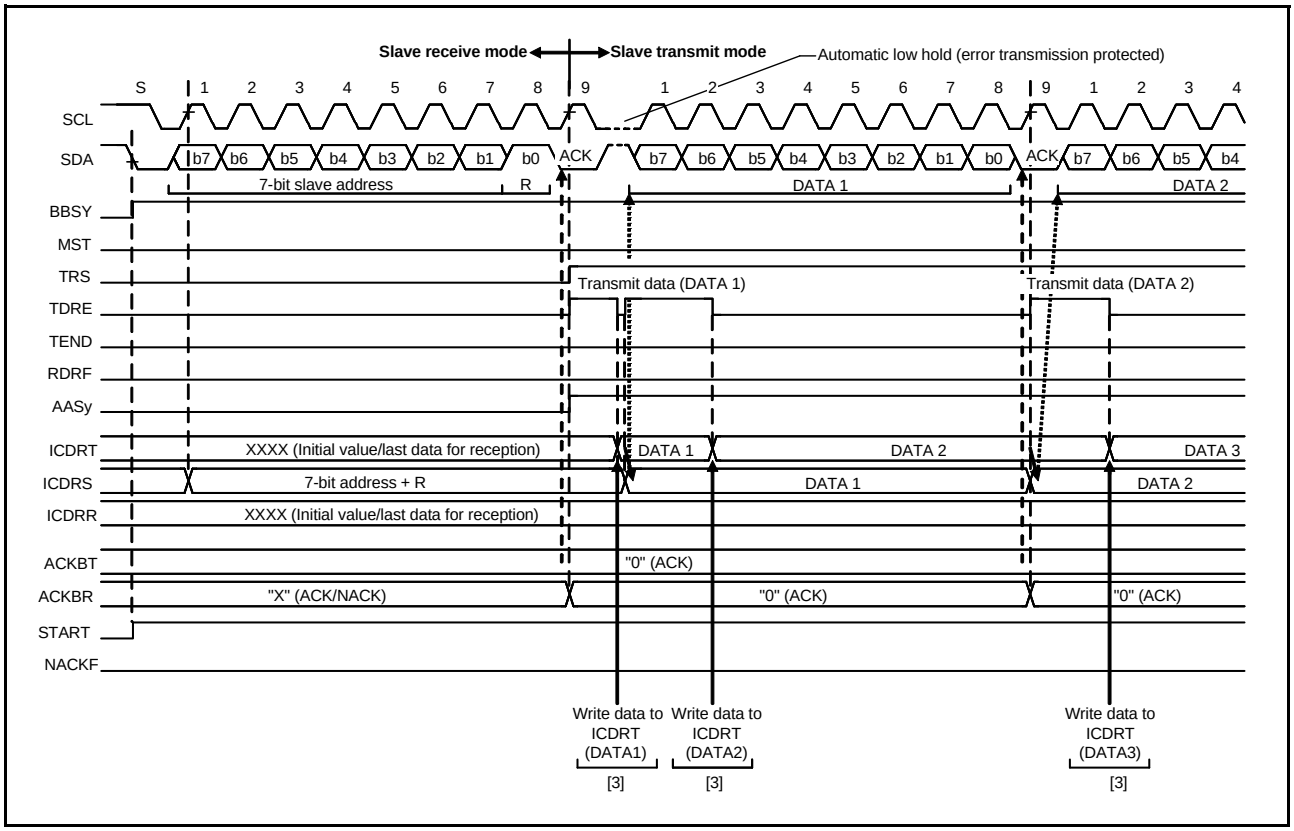


Figure 24.15 Slave Transmit Operation Timing (1) (7-Bit Address Format)

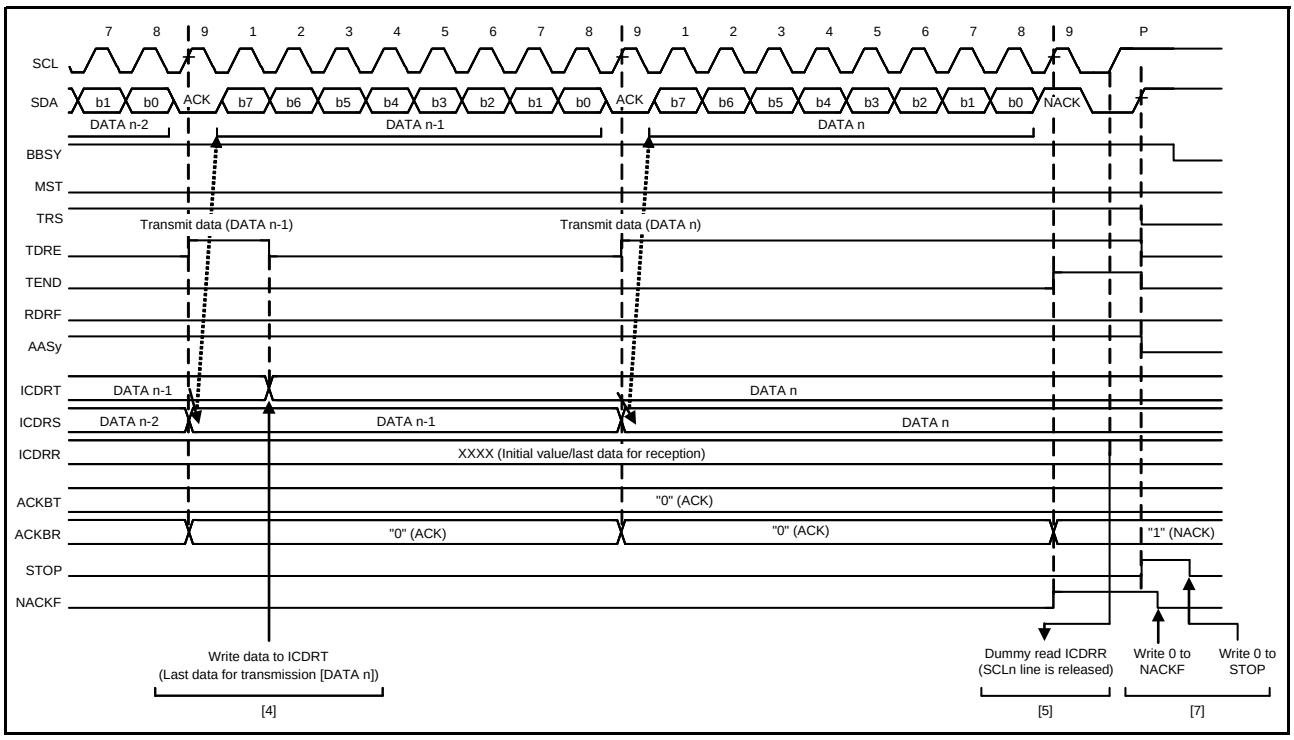


Figure 24.16 Slave Transmit Operation Timing (2)

24.3.6 Slave Receiver Operation

In slave receiver operation, the master device outputs the SCL clock and data, and the RIIC returns acknowledgements as a slave device.

Figure 24.17 shows an example of usage of slave reception and Figure 24.19 and Figure 24.19 show the timing of operations in slave reception.

The following describes the procedure and operations for slave reception.

1. Follow the procedure in Figure 24.5 to make initial settings for the RIIC. This step is not necessary if initialization of the RIIC has already been completed. After initial settings, the RIIC will stay in the standby state until it receives a slave address that it matches.
2. After receiving a matching slave address, the RIIC sets one of the corresponding bits ICSR1.HOA, GCA, and AASy (y = 0 to 2) to 1 on the rising edge of the ninth cycle of SCL clock (the clock signal) and outputs the value set in the ICMR3.ACKBT bit to the acknowledge bit on the ninth cycle of SCL clock. If the value of the R/W# bit that was also received at this time is 1, the RIIC continues to place itself in slave receiver mode and sets the RDRF flag in ICSR2 to 1.
3. After the ICSR2.STOP flag is confirmed to be 0 and the ICSR2.RDRF flag to be 1, dummy read ICDRR (the dummy value consists of the slave address and R/W# bit when the 7-bit address format is selected, or the lower eight bits when the 10-bit address format is selected).
4. When ICDRR is read, the RIIC automatically clears the ICSR2.RDRF flag to 0. If reading of ICDRR is delayed and a next byte is received while the RDRF flag is still set to 1, the RIIC holds the SCL line low from one SCL cycle before the timing with which RDRF should be set. In this case, reading ICDRR releases the SCL line from being held at the low level.
   When the ICSR2.STOP flag is 1 and the ICSR2.RDRF flag is also 1, read ICDRR until all the data is completely received.
5. Upon detecting the stop condition, the RIIC automatically clears bits ICSR1.HOA, GCA, and AASy (y = 0 to 2) to 0.
6. After checking that the ICSR2.STOP flag is 1, clear the ICSR2. STOP flag to 0 for the next transfer operation.

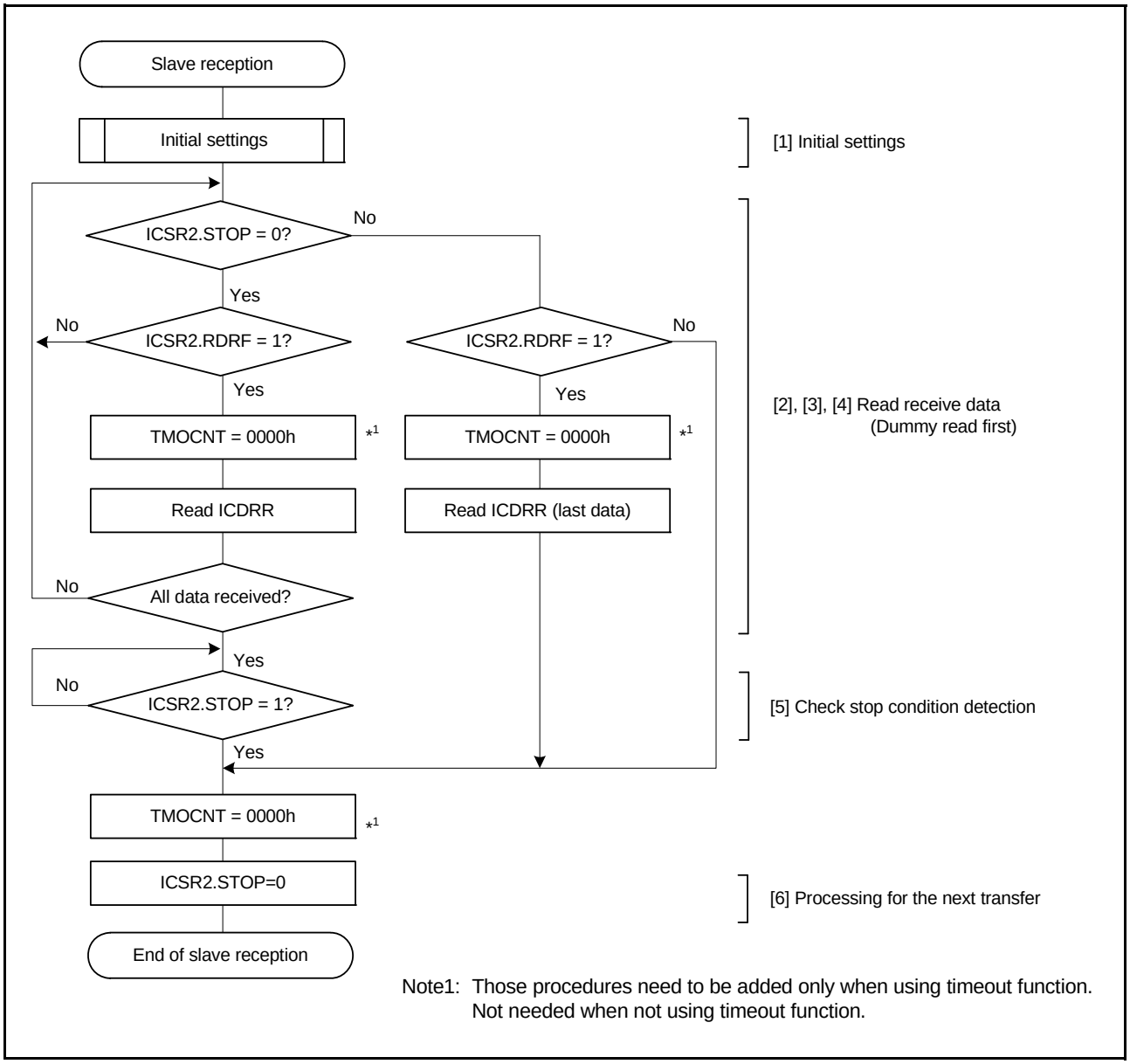


Figure 24.17 Example of Slave Reception Flowchart

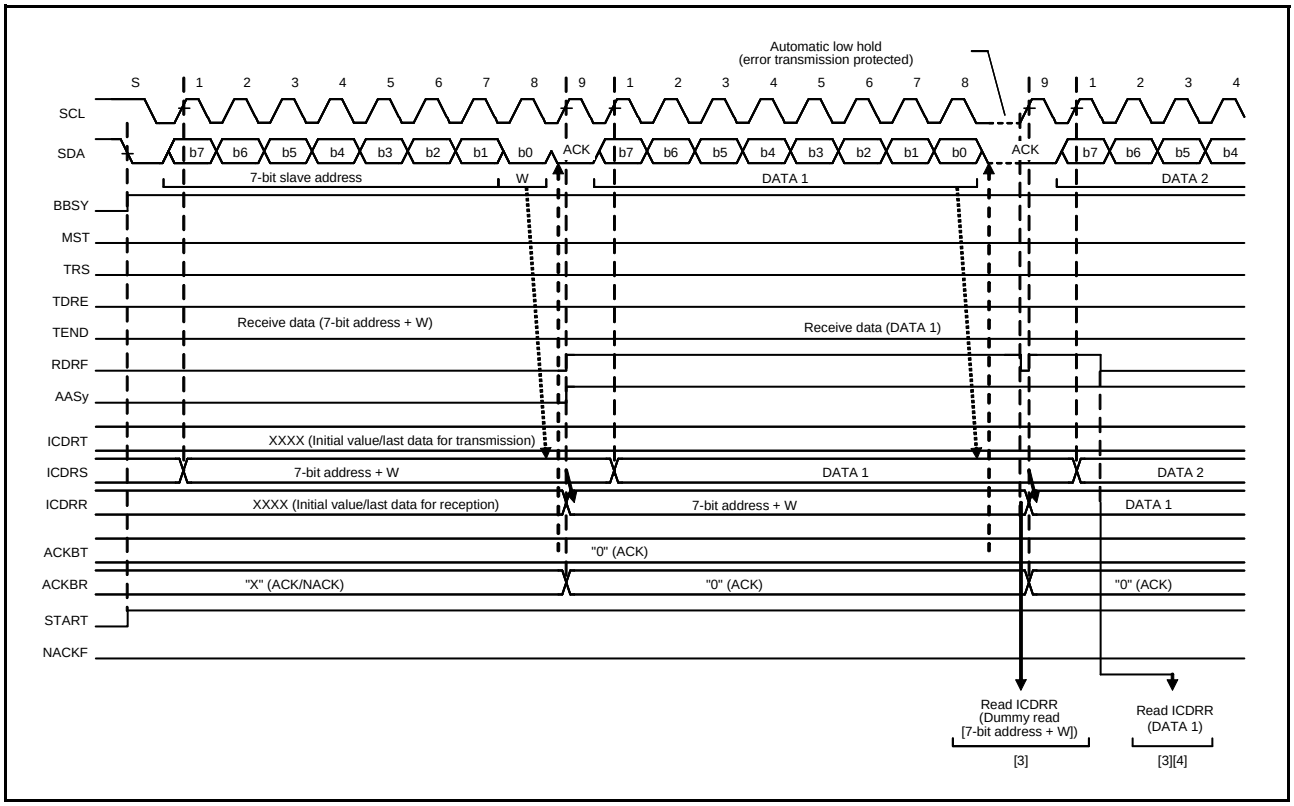


Figure 24.18 Slave Receive Operation Timing (1) (7-Bit Address Format, when RDRFS=0)

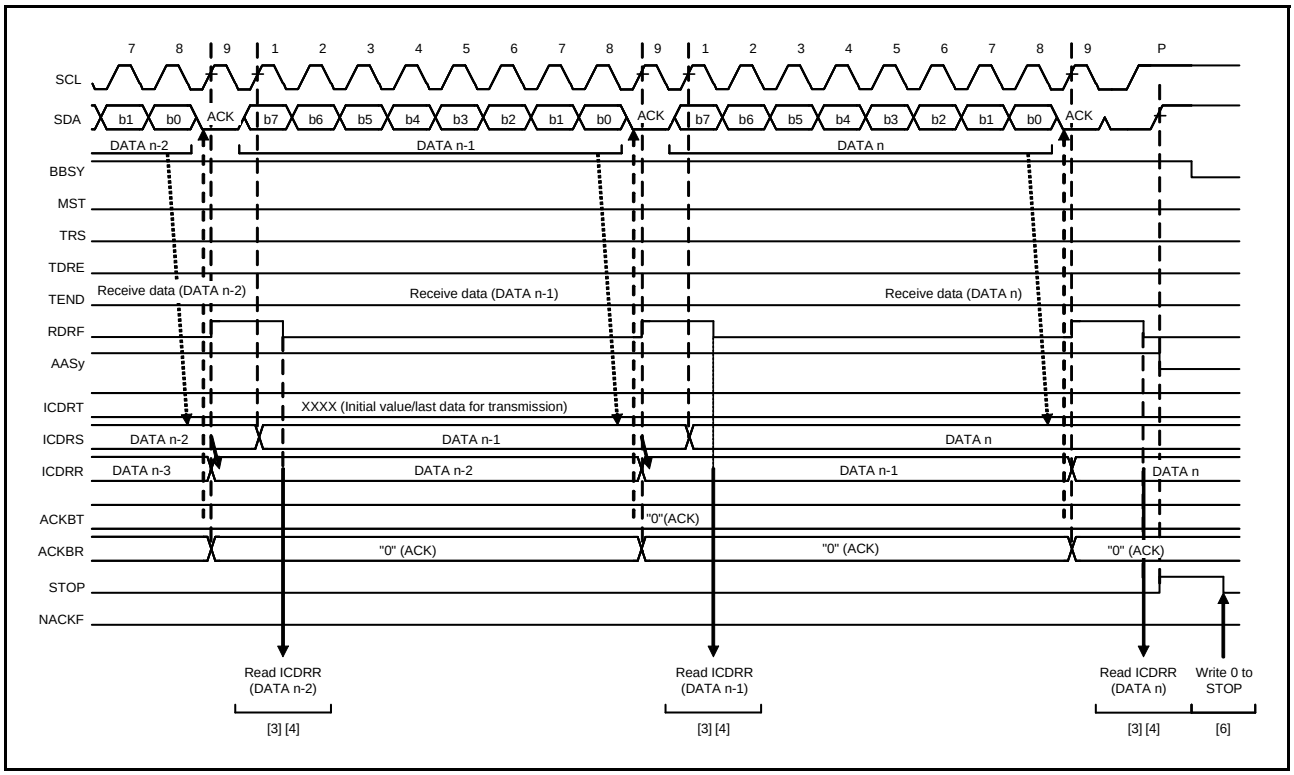


Figure 24.19 Slave Receive Operation Timing (2) (when RDRFS=0)

24.4 SCL Synchronization Circuit

In generation of the SCL (clock) signal, the RIIC starts counting out the value for width at high level specified in ICBRH when it detects a rising edge on the SCL line and drives the SCL line low once counting of the width at high level is complete. When the RIIC detects the falling edge of the SCL line, it starts counting out the width at low level period specified in ICBRL, and then stops driving the SCL line (releases the line) once counting of the width at low level is complete. The SCL (clock) signal is thus generated.

If multiple master devices are connected to the I^{2}C bus, a collision of SCL signals may arise due to contention with another master device. In such cases, the master devices have to synchronize their SCL signals. Since this synchronization of SCL signals must be bit by bit, the RIIC is equipped with a facility (the SCL synchronization circuit) to obtain bit-by-bit synchronization of the SCL clock signals by monitoring the SCL line while in master mode.

When the RIIC has detected a rising edge on the SCL line and thus started counting out the width at high level specified in ICBRH, and the level on the SCL line falls because an SCL signal is being generated by another master device, the RIIC stops counting when it detects the falling edge, drives the level on the SCL line low, and starts counting out the width at low level specified in ICBRL. When the RIIC finishes counting out the width at low level, it stops driving the SCL line to the low level (i.e. releases the line). At this time, if the width at low level of the SCL clock signal from the other master device is longer than the width at low level set in the RIIC, the width at low level of the SCL signal will be extended. Once the width at low level for the other master device has ended, the SCL signal rises because the SCL line has been released. When the RIIC finishes outputting the low-level period of the SCL clock of, the SCL line is released and the SCL clock rises. That is, in cases of contention of SCL signals from more than one master, the width at high level of the SCL signal is synchronized with that of the clock having the narrower width, and the width at low level of the SCL signal is synchronized with that of the clock having the broader width. However, such synchronization of the SCL signal is only enabled when the SCLE bit in ICFER is set to 1.

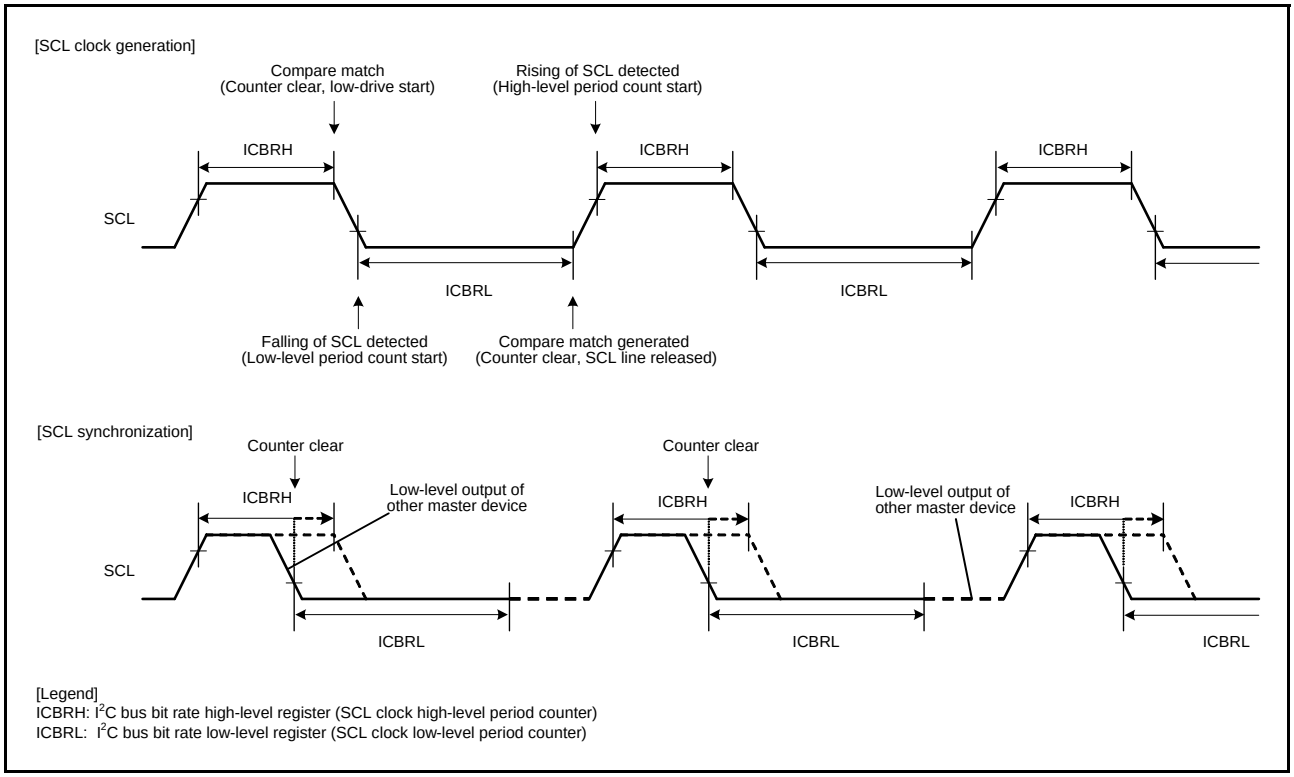


Figure 24.20 Generation and Synchronization of the SCL Signal from the RIIC

24.5 Facility for Delaying SDA Output

The RIIC module incorporates a facility for delaying output on the SDA line. The delay can be applied to all output (issuing of the start, restart, and stop conditions, data, and the ACK and NACK signals) on the SDA line.

With the SDA output delay facility, SDA output is delayed from detection of a falling edge of the SCL signal to ensure that the SDA signal is output within the interval over which the SCL (clock) signal is at the low level. Doing this leads to usage with the aim of preventing erroneous operation of communications devices, with the aim of satisfying the 300-ns (min.) data-hold time requirement of the SMBus specification.

The output delay facility is enabled by setting the SDDL[2:0] bits in IMCR2 to any value other than 000b, and disabled by setting the same bits to 000b.

While the SDA output delay facility is enabled (i.e. while the SDDL[2:0] bits in IMCR2 are set to any value other than 000b), the DLCS bit in IMCR2 selects the clock source for counting by the SDA output delay counter as the internal base clock (IICϕ) for the RIIC module or as a clock signal derived by dividing the frequency of the internal base clock by two (IICϕ/2). The counter counts the number of cycles set in the SDDL[2:0] bits in IMCR2. After counting of the set number of cycles of delay is completed, the RIIC module places the required output (start, restart, or stop condition, data, or an ACK or NACK signal) on the SDA line.

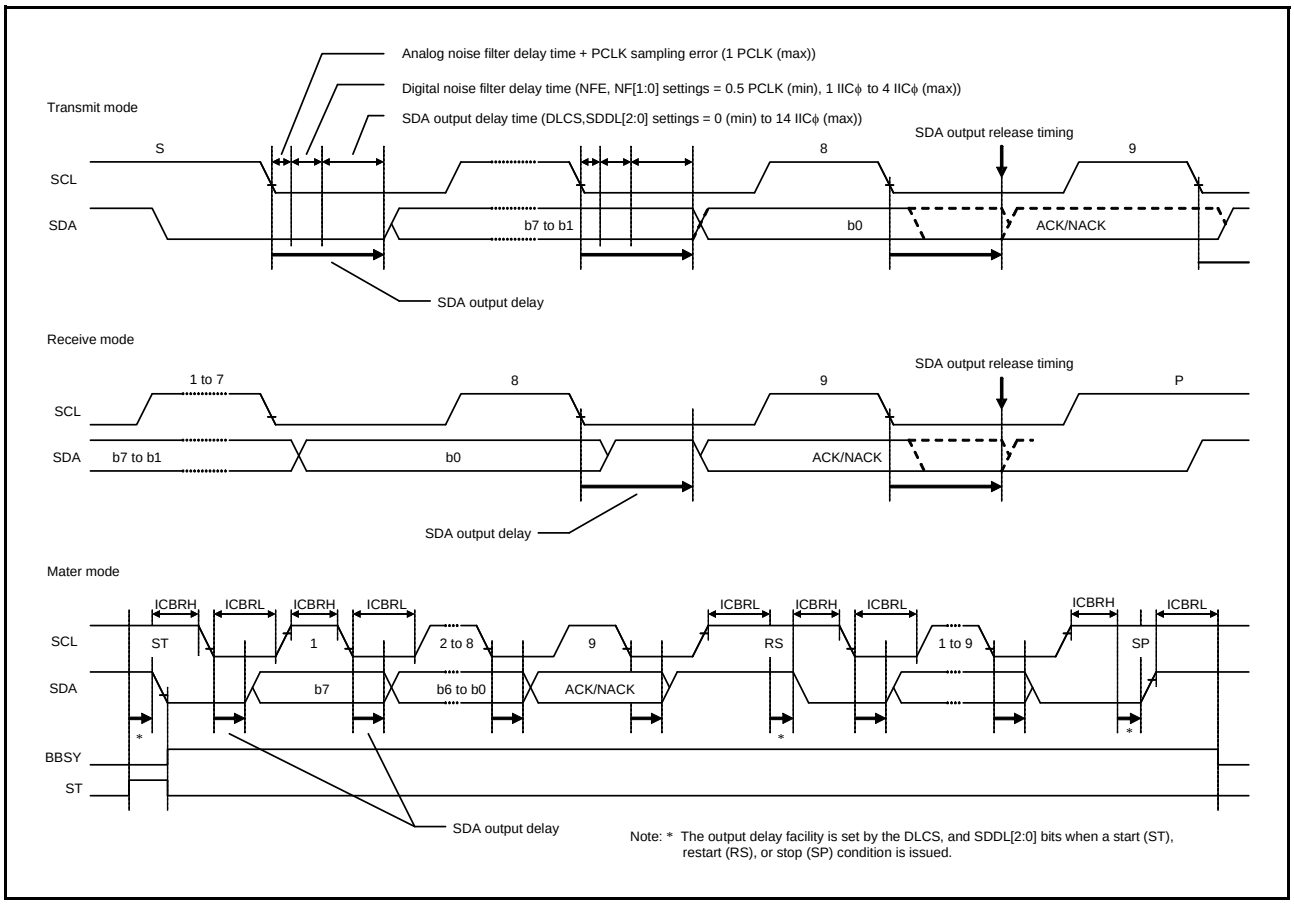


Figure 24.21 SDA Output Delay Facility

24.6 Digital Noise-Filter Circuits

The states of the SCL and SDA pins are conveyed to the internal circuitry through analog noise-filter and digital noise-filter circuits. Figure 24.22 is a block diagram of the digital noise-filter circuit.

The on-chip digital noise-filter circuit of the RIIC consists of four flip-flop circuit stages connected in series and a match-detection circuit.

The number of effective stages in the digital noise filter is selected by the NF[1:0] bits in ICMR3. The selected number of effective stages determines the noise-filtering capability as a period from one to four IICϕ cycles.

The input signal to the SCL pin (or SDA pin) is sampled on falling edges of the PCLK signal. When the input signal level matches the output level of the number of effective flip-flop circuit stages as selected by the NF[1:0] bits in ICMR3, the signal level is conveyed to the subsequent stage. If the signal levels do not match, the previous value is retained.

If the ratio between the frequency of the internal operating clock (PCLK) and the transfer rate is small (e.g. data transfer at 400 kbps with PCLK = 4 MHz), the characteristics of the digital noise filter may lead to the elimination of needed signals as noise. In such cases, it is possible to disable the digital noise-filter circuit (by clearing the NFE bit in ICFER) and use only the analog noise-filter circuit.

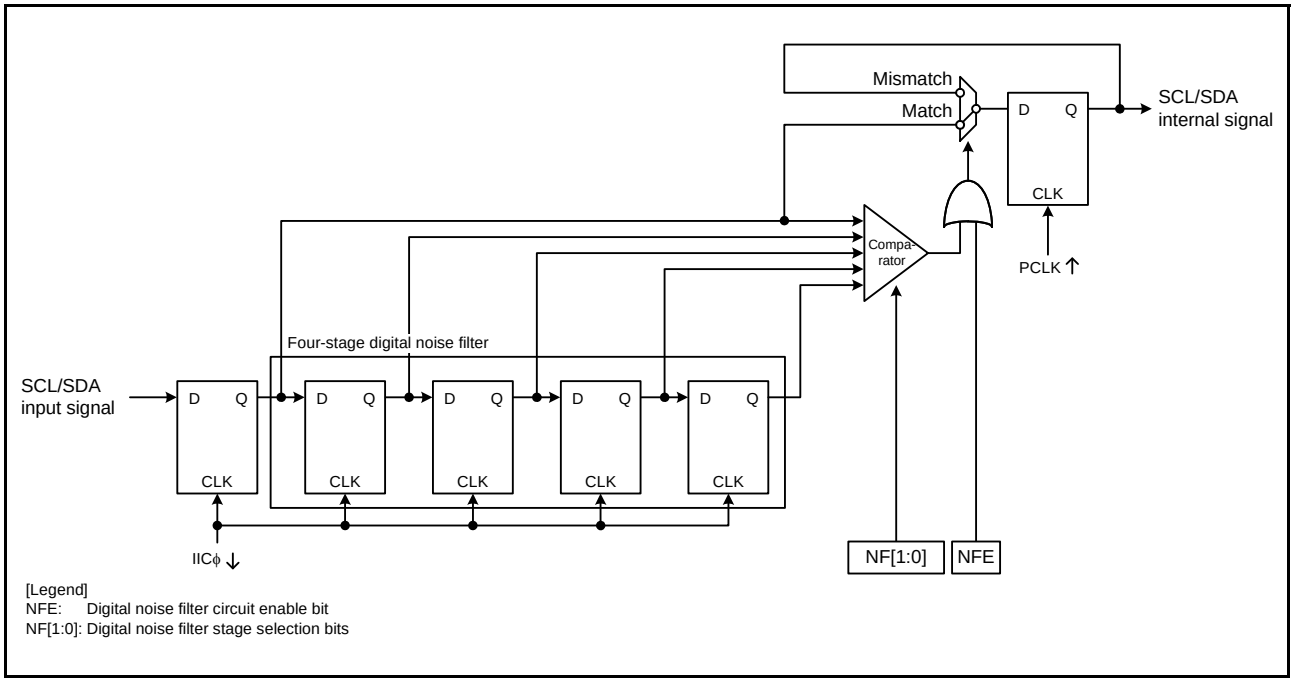


Figure 24.22 Block Diagram of Digital Noise Filter Circuit

24.7 Address Match Detection

The RIIC can set three unique slave addresses in addition to the general call address and host address, and also can set 7-bit or 10-bit slave addresses.

24.7.1 Slave-Address Match Detection

The RIIC can set three unique slave addresses, and has a slave address detection function for each unique slave address. When the SARyE bit (y = 0 to 2) in ICSER is set to 1, the slave addresses set in SARUy and SARLy (y = 0 to 2) can be detected.

When the RIIC detects a match of the set slave address, the corresponding AASy flag (y = 0 to 2) in ICSR1 is set to 1 at the rising edge of the ninth SCL clock cycle, and the RDRF flag in ICSR2 or the TDRE flag in ICSR2 is set to 1 by the following R/W# bit. This causes a receive data full interrupt (ICRXI) or transmit data empty interrupt (ICTXI) to be generated. The AASy flag is used to identify which slave address has been specified.

Figure 24.23 to Figure 24.25 show the AASy (y = 0 to 2) flag set timing in three cases.

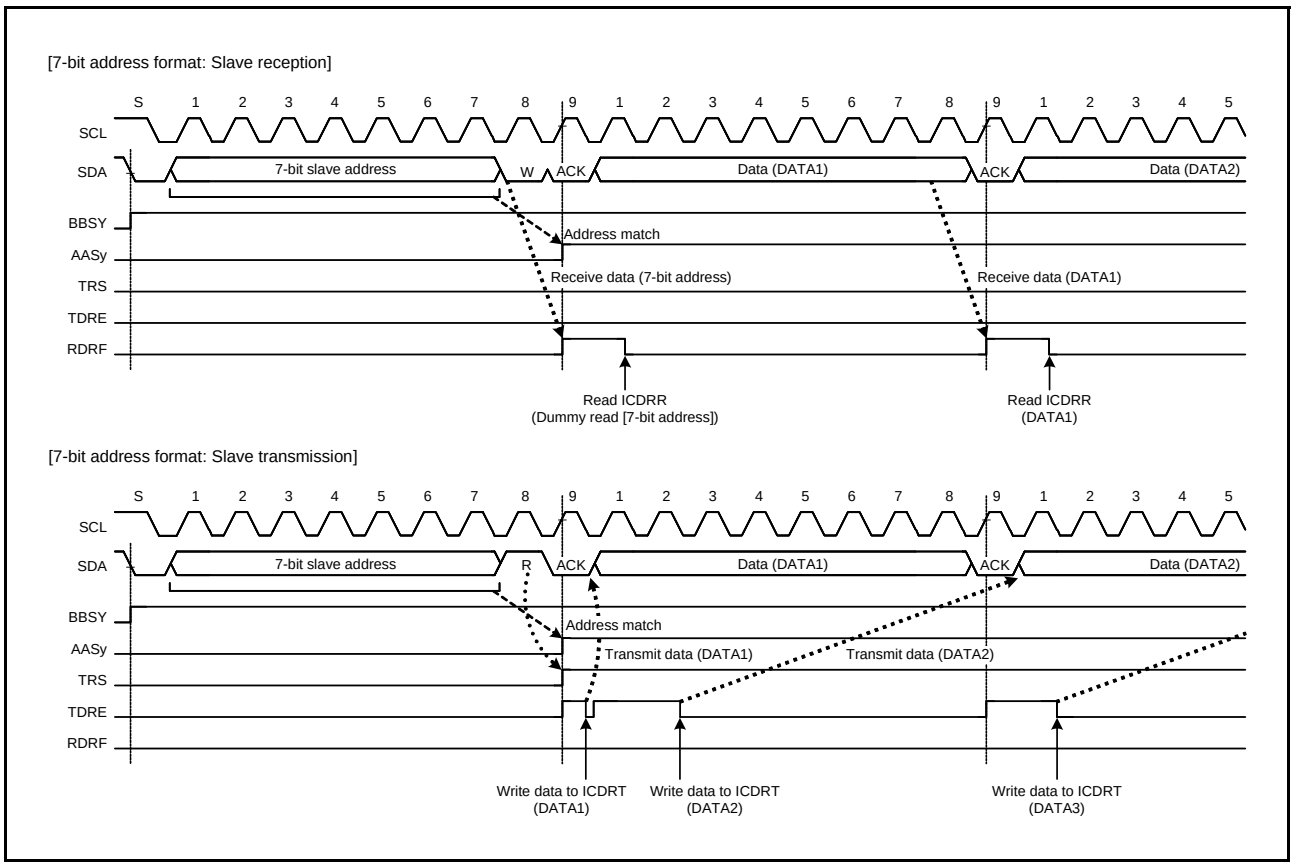


Figure 24.23 AASy Flag Set Timing with 7-Bit Address Format Selected

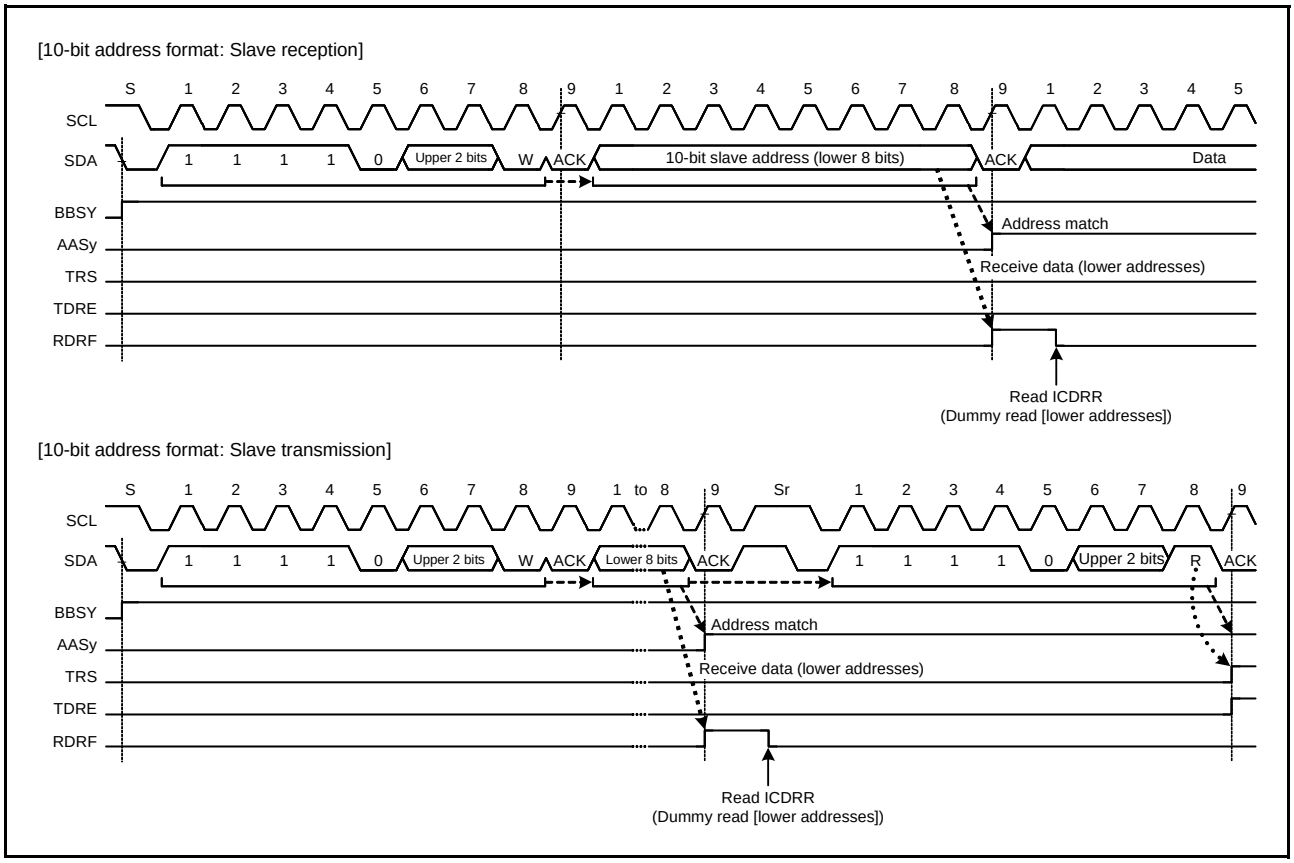


Figure 24.24 AASy Flag Set Timing with 10-Bit Address Format Selected

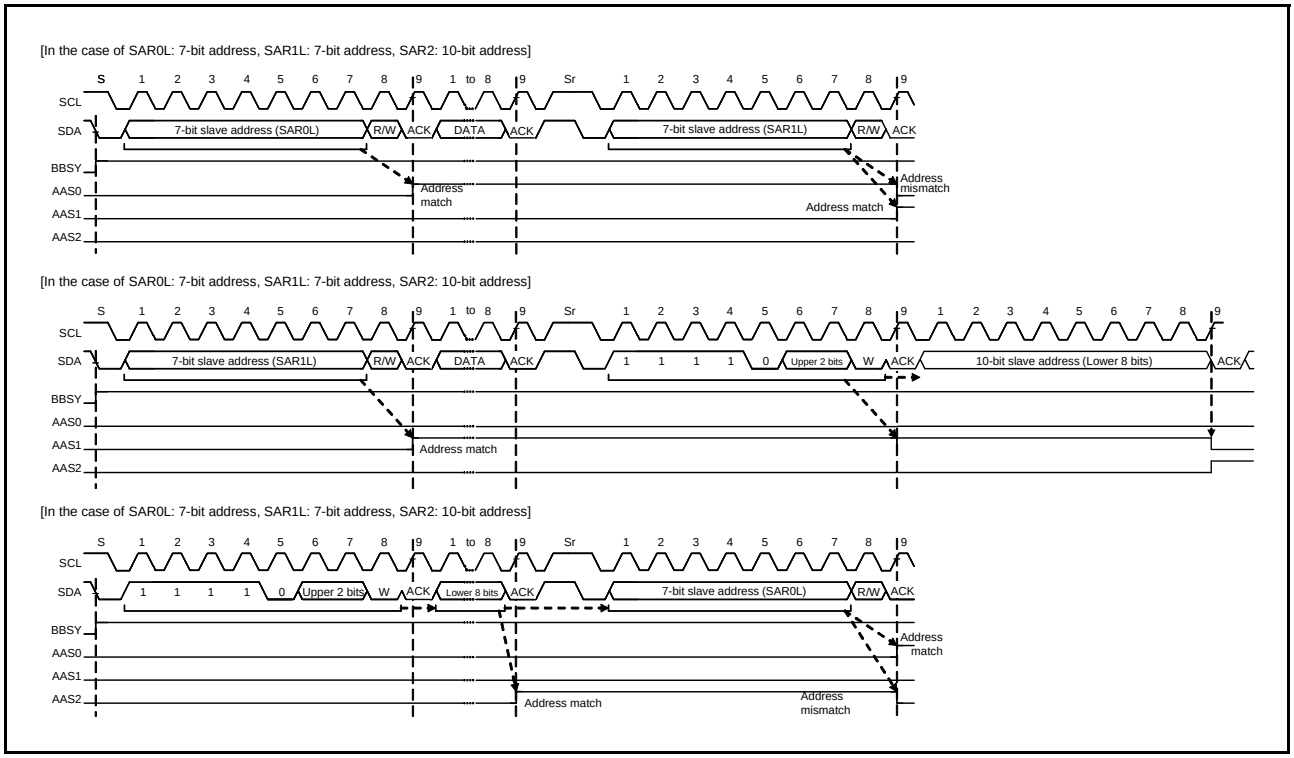


Figure 24.25 AASy Flag Set/Clear Timing with 7-Bit/10-Bit Address Formats Mixed

24.7.2 Detection of the General Call Address

The RIIC has a facility for detecting the general call address (0000 000b + 0 [W]). This is enabled by setting the GCAE bit in ICSER to 1.

If the address received after a start or restart condition is issued is 0000 000b + 1[R] (start byte), the RIIC recognizes this as the address of a slave device with an "all-zero" address but not as the general call address.

When the RIIC detects the general call address, both the GCA flag in ICSR1 and the RDRF flag in ICSR2 are set to 1 on the rising edge of the ninth cycle of SCL clock. This leads to the generation of a receive data full interrupt (ICRXI). The value of the GCA flag can be confirmed to recognize that the general call address has been transmitted.

Operation after detection of the general call address is the same as normal slave receive operation.

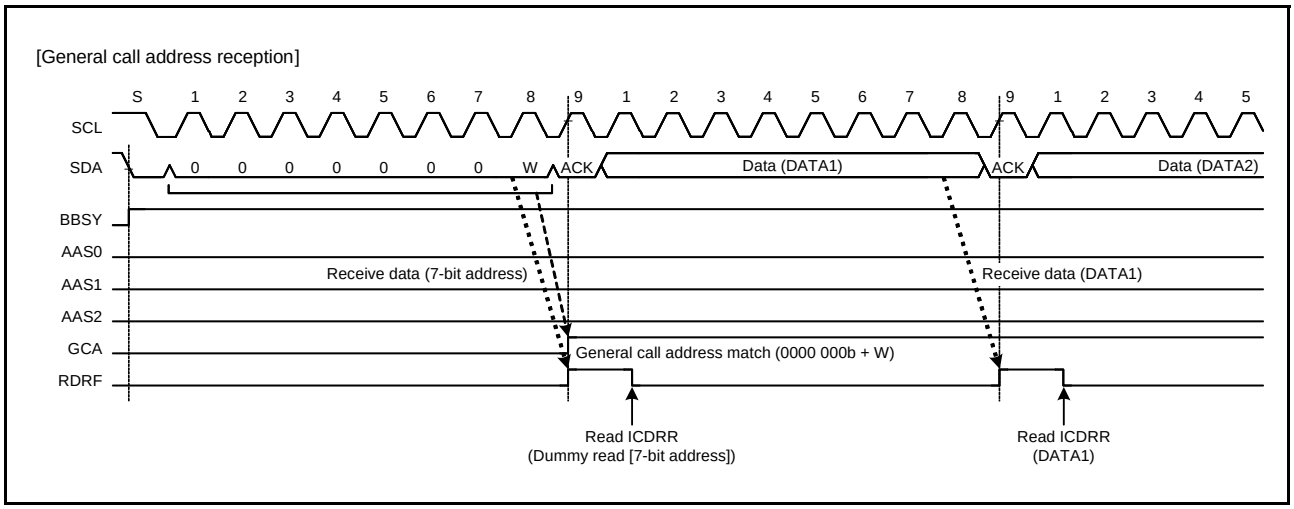


Figure 24.26 Timing of GCA Flag Setting during Reception of General Call Address

24.7.3 Device-ID Address Detection

The RIIC module has a facility for detecting device-ID addresses conformant with the I2C bus standard (Rev. 03). When the RIIC receives 1111 100b as the first byte after a start condition or restart condition was issued with the DIDE bit in ICSER set to 1, the RIIC recognizes the address as a device ID, sets the DID flag in ICSR1 to 1 on the rising edge of the ninth SCL clock cycle when the following R/W# bit is 0, and then compares the second and subsequent bytes with its own slave address. If the address matches the value in the slave address register, the RIIC sets the corresponding AASy flag (y = 0 to 2) in ICSR1 to 1.

After that, when the first byte received after a start condition or restart condition is issued matches the device ID address (1111 100b) again and the following R/W# bit is 1, the RIIC does not compare the second and subsequent bytes and sets the ICSR2.TDRE flag to 1.

In the device-ID address detection function, the RIIC clears the DID flag to 0 if a match with the RIIC's own slave address is not obtained or a match with the device ID address is not obtained after a match with the RIIC's own slave address and the detection of a restart condition. If the first byte after detection of a start or restart condition matches the device ID address (1111 100b) and the R/W# bit is 0, the RIIC sets the DID flag to 1 and compares the second and subsequent bytes with the RIIC's slave address. If the R/W# bit is 1, the DID flag holds the previous value and the RIIC does not compare the second and subsequent bytes. Therefore, the reception of a device-ID address can be checked by reading the DID flag after confirming that TDRE = 1.

Furthermore, prepare the device-ID fields (three bytes: 12 bits indicating the manufacturer + 9 bits identifying the part + 3 bits indicating the revision) that must be sent to the host after reception of a continuous device-ID field as normal data for transmission. For details of the information that must be included in device-ID fields, contact NXP Semiconductors.

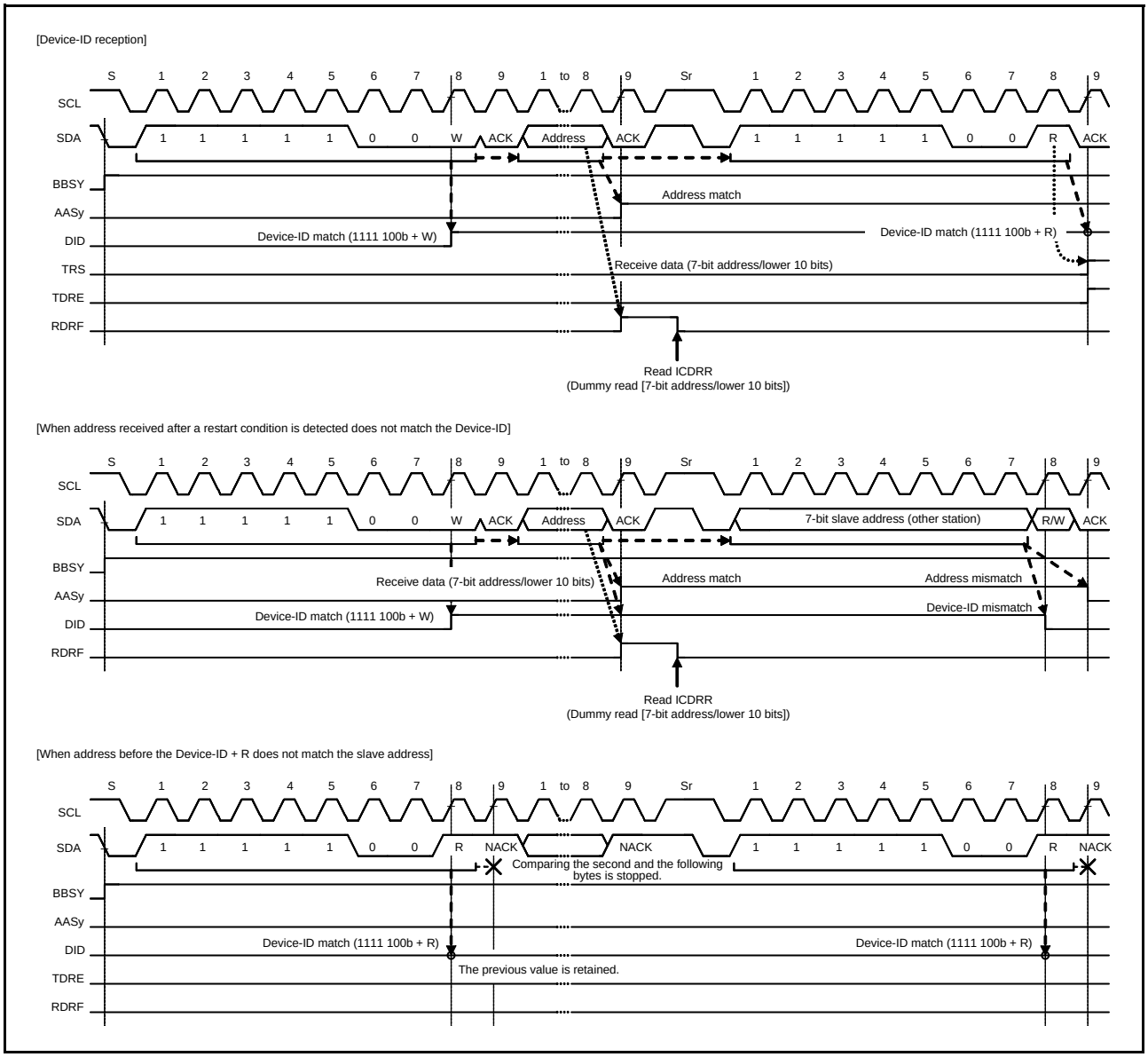


Figure 24.27 AASy/DID Flag Set/Clear Timing during Reception of Device-ID

24.7.4 Host Address Detection

The RIIC has a function to detect the host address while the SMBus is operating. When the HOAE bit in ICSER is set to 1 while the SMBS bit in ICMR3 is 1, the RIIC can detect the host address (0001 000b) in slave receive mode (MST and TRS bits = 00b in ICCR2).

When the RIIC detects the host address, the HOA flag in ICSR1 is set to 1 at the rising edge of the ninth SCL clock cycle, and at the same time, the TDRE flag in ICSR2 is set to 1 when the R/W# bit is 0 (Wr bit). This causes a transmit data empty interrupt (ICTXI) to be generated. The HOA flag is used to recognize that the host address was sent from the smart battery or other devices.

If the bit following the host address (0001 000b) is an Rd bit (R/W# bit = 1), the RIIC can also detect the host address. After the host address is detected, the RIIC operates in the same manner as normal slave operation.

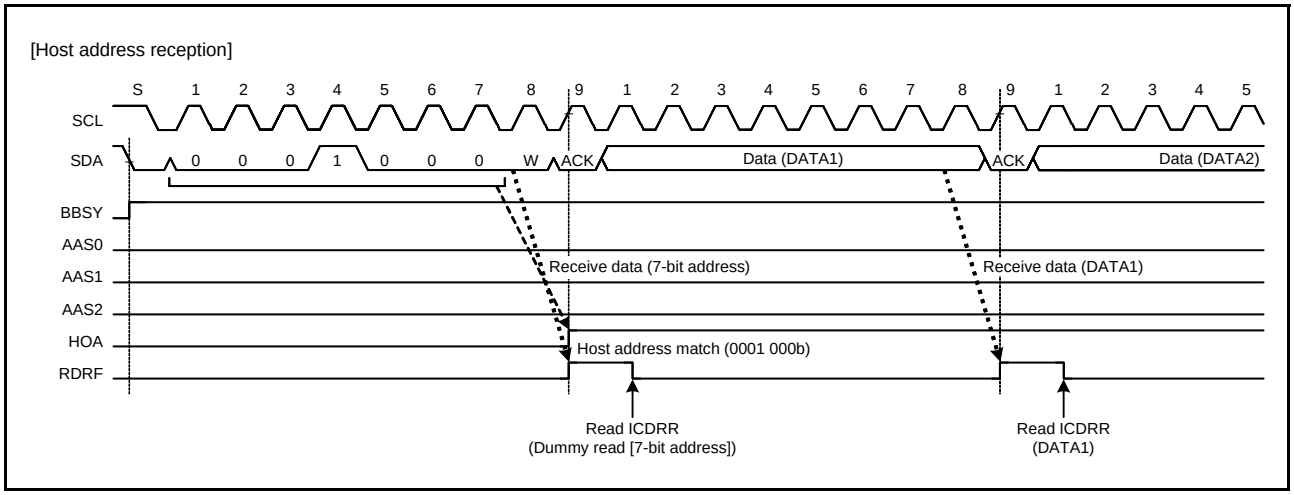


Figure 24.28 HOA Flag Set Timing during Reception of Host Address

24.8 Function to Automatically Hold SCL Clock Low

24.8.1 Function to Prevent Wrong Transmission of Transmit Data

If the shift register (ICDRS) is empty when data have not been written to the transmit data register (ICDRT) with the RIIC in transmission mode (TRS bit = 1 in ICCR2), the SCL signal is automatically held at the low level over the intervals shown below. This low-hold period is extended until data for transmission have been written, which prevents the unintended transmission of erroneous data.

<Master transmitter mode>

- Low-level interval after a start condition or restart condition is issued
- Low-level interval of one clock cycle between the ninth clock cycle of one transfer and the first clock cycle of the next

<Slave transmitter mode>

- Low-level interval between the ninth clock cycle of one transfer and the first clock cycle of the next

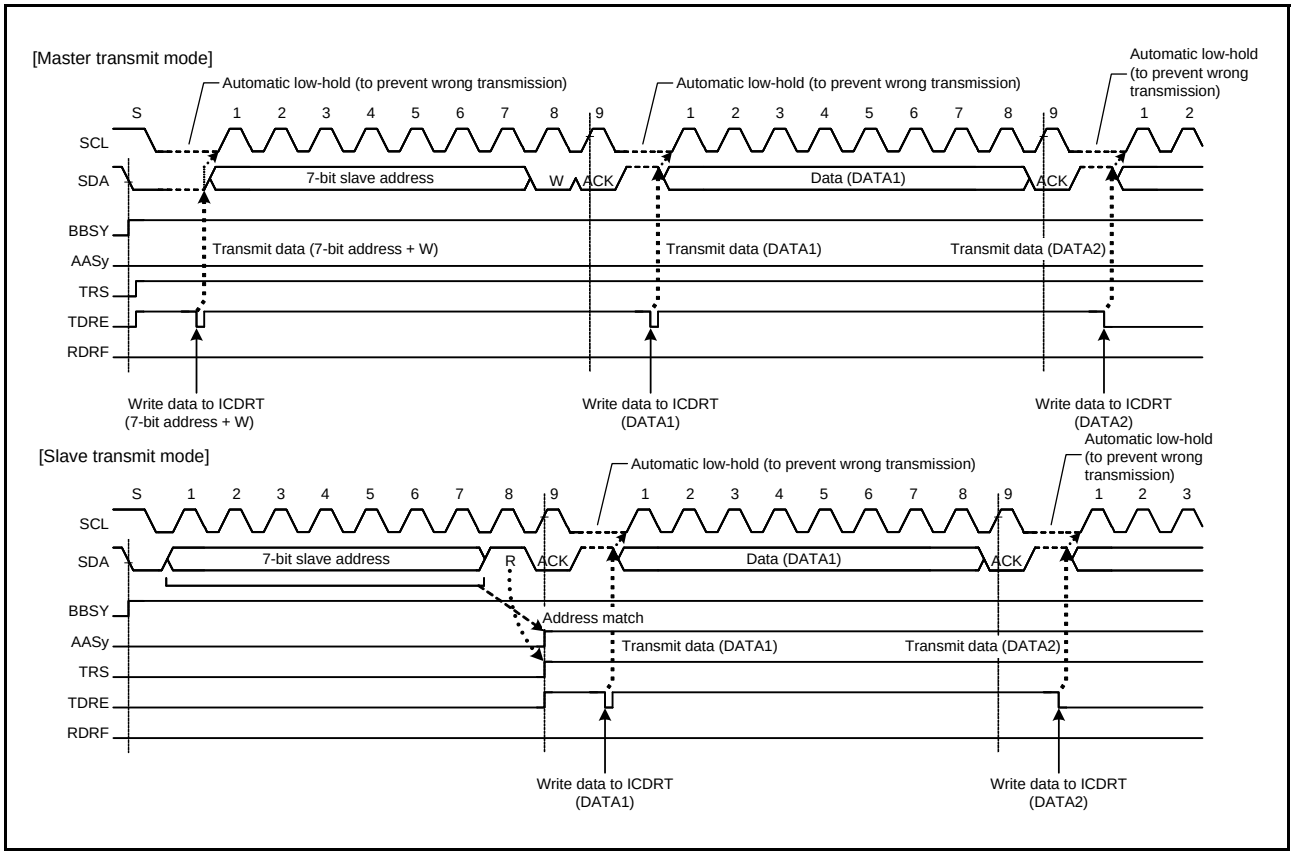


Figure 24.29 Automatic Low-Hold Operation in Transmit Mode

24.8.2 NACK Reception Transfer Suspension Function

The RIIC has a function to suspend transfer operation when NACK is received in transmit mode (TRS bit = 1 in ICCR2). This function is enabled when the NACKE bit in ICFER is set to 1 (transfer suspension enabled). If the next transmit data has already been written (TDRE flag = 0 in ICSR2) when NACK is received, next data transmission at the falling edge of the ninth SCL clock cycle is automatically suspended. This prevents the SDA line output level from being held low when the MSB of the next transmit data is 0.

If the transfer operation is suspended by this function (NACKF flag = 1 in ICSR2), transmit operation and receive operation are discontinued. To restore transmit/receive operation, be sure to clear the NACKF flag to 0. In master transmit mode, clear the NACKF flag to 0, issue a restart or stop condition, and then issue a start condition again.

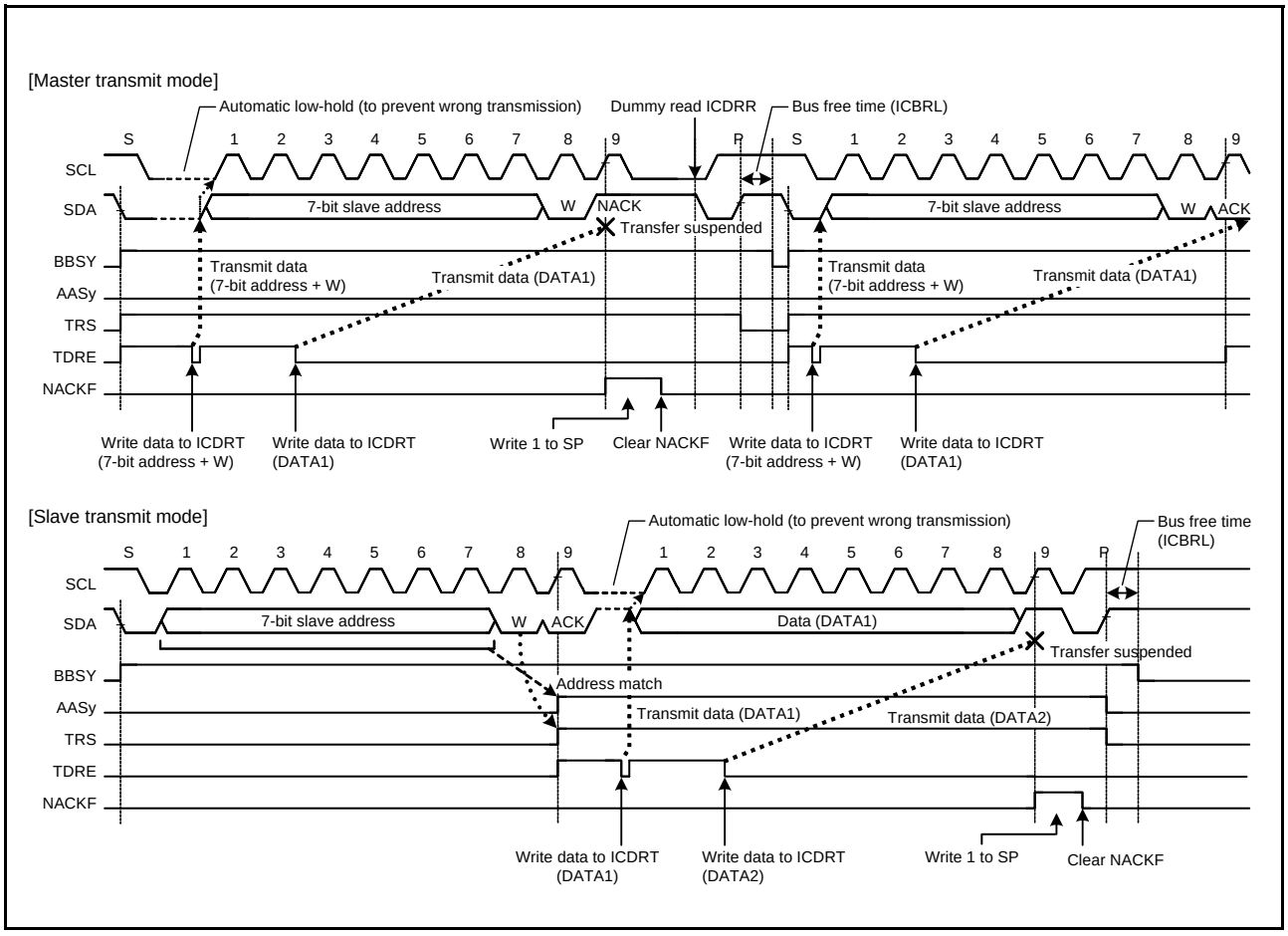


Figure 24.30 Suspension of Data Transfer when NACK is Received (NACKE = 1)

24.8.3 Function to Prevent Failure to Receive Data

If response processing is delayed when receive data (ICDRR) read is delayed for a period of one transfer frame or more with receive data full (RDRF flag = 1 in ICSR2) in receive mode (TRS = 0 in ICCR2), the RIIC holds the SCL line low automatically immediately before the next data is received to prevent failure to receive data.
This function to prevent failure to receive data using the automatic low-hold function is also enabled even if the read processing of the final receive data is delayed and, in the meantime, the RIIC's own slave address is designated after a stop condition is issued. This function does not disturb other communication because the RIIC does not hold the SCL line low when a mismatch with its own slave address occurs after a stop condition is issued.
Sections in which the SCL line is held low can be selected with a combination of the WAIT and RDRFS bits in ICMR3.

(1) One-Byte Receive Operation and Automatic Low-Hold Function Using the WAIT Bit

When the WAIT bit in ICMR3 is set to 1, the RIIC performs one-byte receive operation using the WAIT bit function. Furthermore, when the ICMR3.RDRFS bit is 0, the RIIC automatically sends the ACKBT bit value in ICMR3 for the acknowledge bit in the period from the falling edge of the eighth SCL clock cycle to the falling edge of the ninth SCL clock cycle, and automatically holds the SCL line low at the falling edge of the ninth SCL clock cycle using the WAIT bit function. This low-hold is released by reading data from ICDRR, which enables bytewise receive operation.
The WAIT bit function is enabled for receive frames after a match with the RIIC's own slave address (including the general call address and host address) is obtained in master receive mode or slave receive mode.

(2) One-Byte Receive Operation (ACK/NACK Transmission Control) and Automatic Low-Hold Function Using the RDRFS Bit

When the RDRFS bit in ICMR3 is set to 1, the RIIC performs one-byte receive operation using the RDRFS bit function. When the RDRFS bit is set to 1, the RDRF flag (receive data full) in ICSR2 is set to 1 at the rising edge of the eighth SCL clock cycle, and the SCL line is automatically held low at the falling edge of the eighth SCL clock cycle. This low-hold is released by writing a value to the ACKBT bit in ICMR3, but cannot be released by reading data from ICDRR, which enables receive operation by the ACK/NACK transmission control according to the data received in byte units.
The RDRFS bit function is enabled for receive frames after a match with the RIIC’s own slave address (including the general call address and host address) is obtained in master receive mode or slave receive mode.

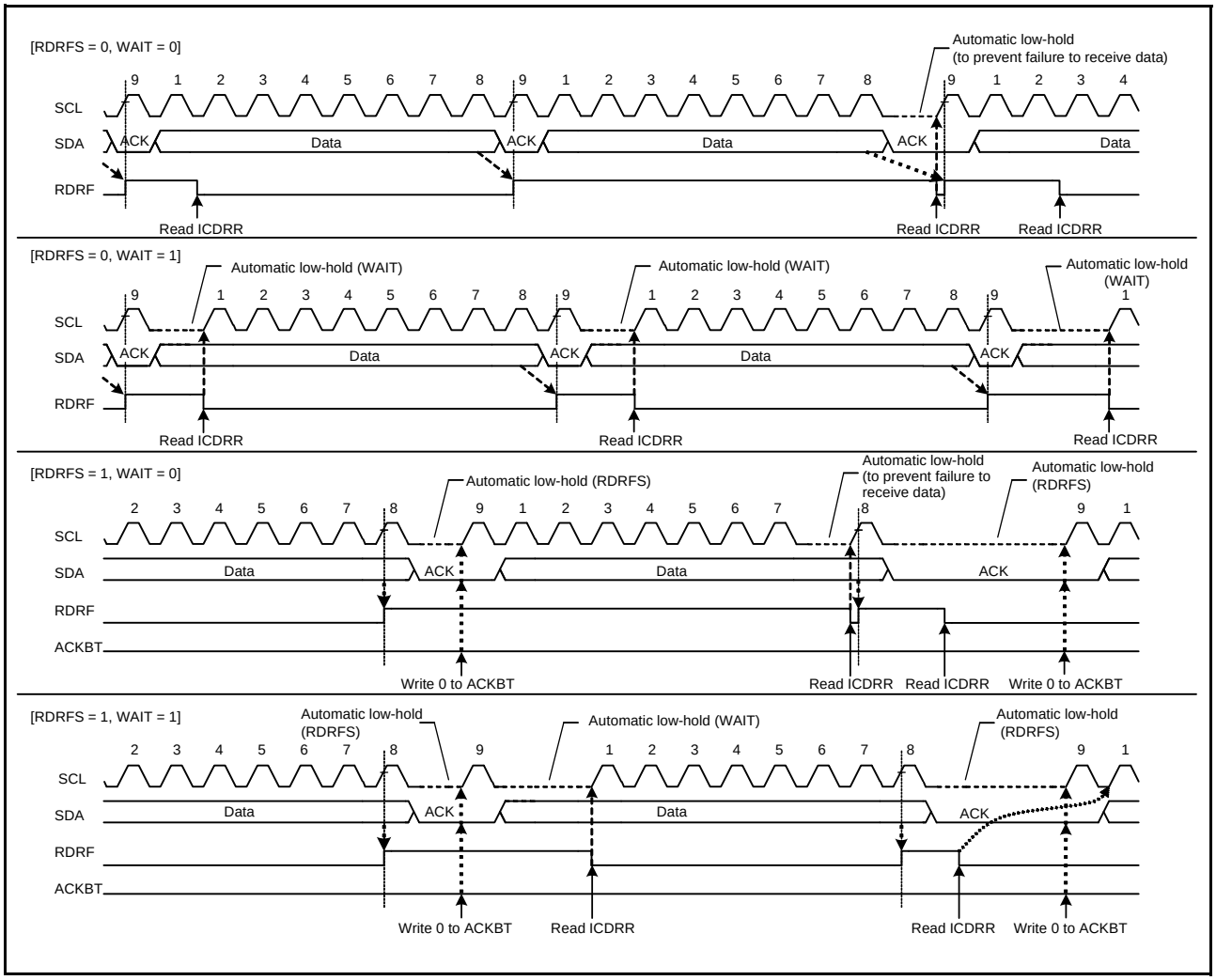


Figure 24.31 Automatic Low-Hold Operation in Receive Mode (Using RDRFS and WAIT Bits)

24.9 Arbitration-Lost Detection Functions

In addition to the normal arbitration-lost detection function defined by the I^2C bus standard, the RIIC has functions to prevent double-issue of a start condition, to detect arbitration during transmission of NACK, and to detect arbitration in slave transmit mode.

24.9.1 Master Arbitration Lost Detection (MALE Bit)

The RIIC drives the SDA line low to issue a start condition. However, if the SDA line has already been driven low by another master device issuing a start condition, the RIIC regards its own issuing of a start condition as an error and considers this a loss in arbitration, so priority is given to transfer by the other master device. Similarly, if a request to issue a start condition is made by setting the ST bit in ICCR2 to 1 while the bus is busy (BBSY flag = 1 in ICCR2), the RIIC regards this as a double-issuing-of-start-condition error and considers itself to have lost in arbitration, thus preventing a failure of transfer due to issuing of a start condition while transfer is in progress.
When a start condition is issued successfully, if the data for transmission including the address bits (i.e. the internal SDA output level) and the level on the SDA line do not match (the 1 output as the internal SDA output; i.e. the SDA pin is in the high-impedance state) and the low level is detected on the SDA line, the RIIC loses in arbitration.
After a loss in arbitration of mastership, the RIIC immediately enters slave receiver mode. If a slave address (including the general call address) matches its own address at this time, the RIIC continues in slave operation.
A loss in arbitration of mastership is detected when the following conditions are met while the MALE bit in ICFER is 1 (master arbitration lost detection enabled).

[Master arbitration lost conditions]

- Non-matching of the internal level for output on SDA and the level on the SDA line after a start condition was issued by setting the ST bit in ICCR2 to 1 while the BBSY flag in ICCR2 was cleared to 0 (erroneous issuing of a start condition)
- Setting of the ST bit in ICCR2 to 1 (start condition double-issue error) while the BBSY flag is set to 1
- When the transmit data excluding acknowledge (internal SDA output level) does not match the level on the SDA line in master transmit mode (MST and TRS bits = 11b in ICCR2)

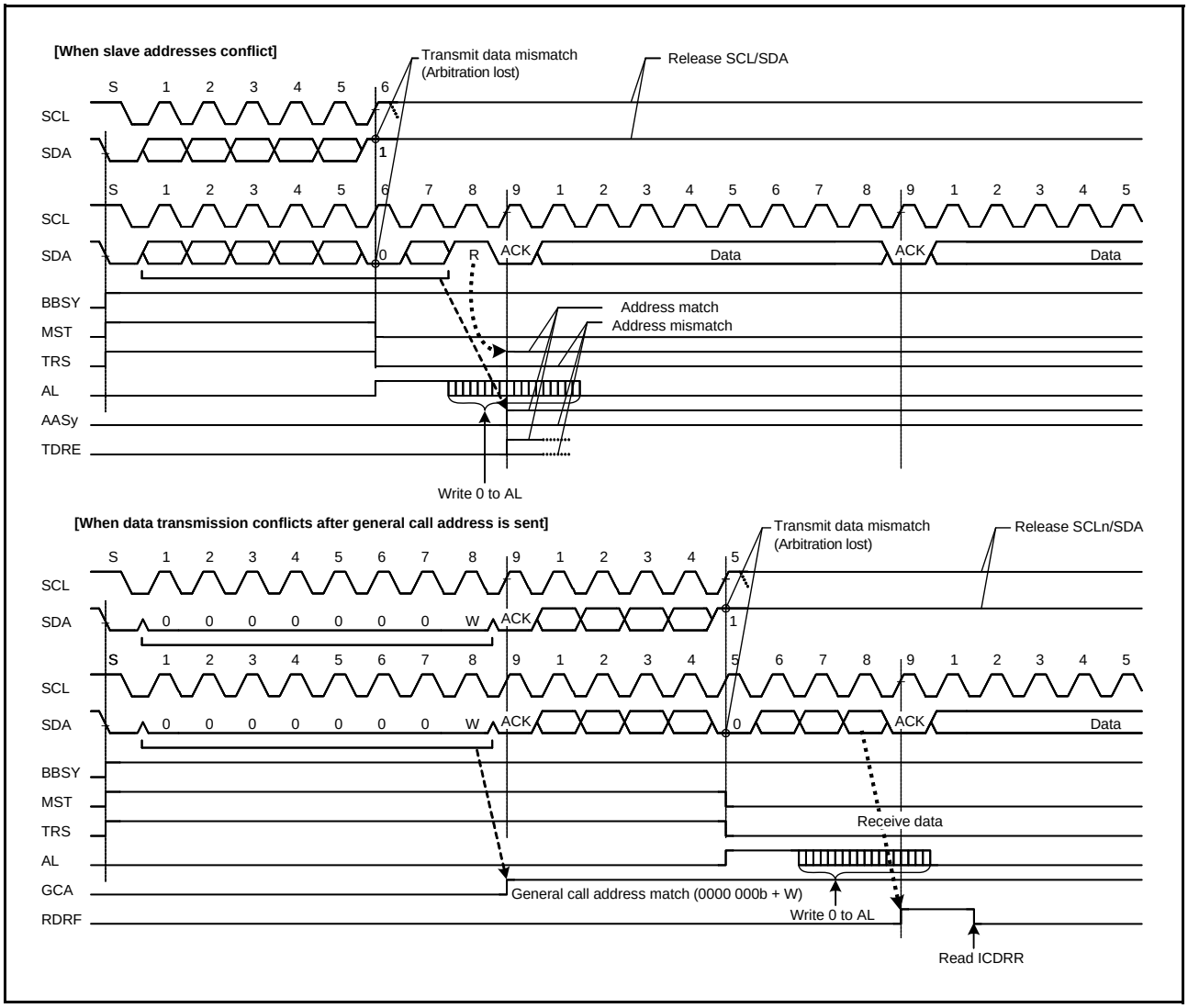


Figure 24.32 Examples of Master Arbitration Lost Detection (MALE = 1)

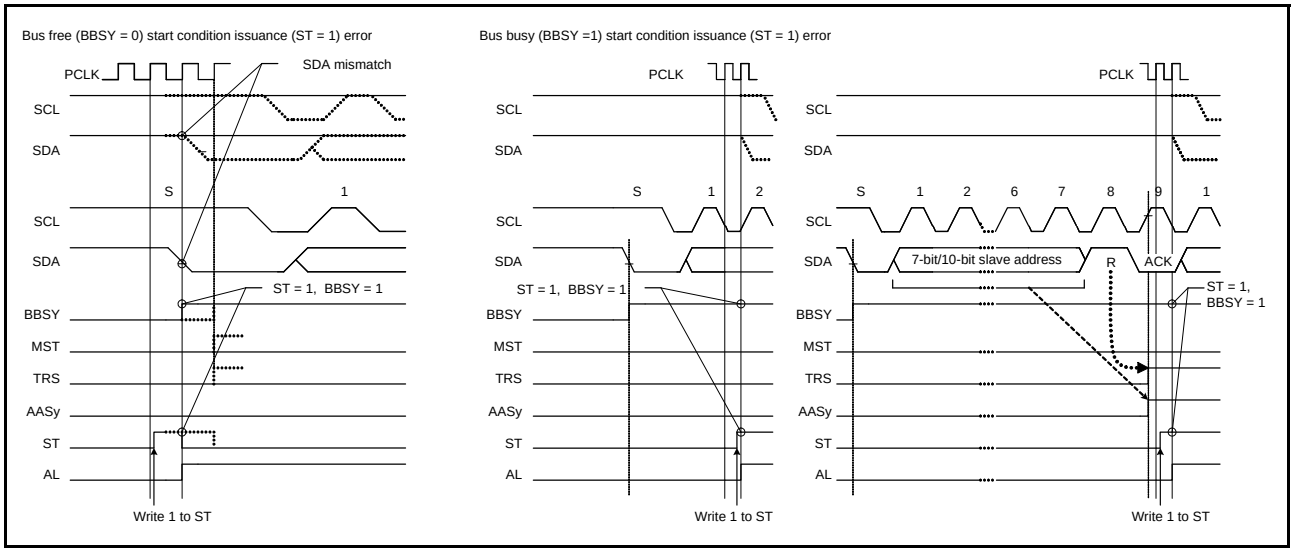


Figure 24.33 Arbitration Lost when a Start Condition is Issued (MALE = 1)

24.9.2 Function to Detect Loss of Arbitration during NACK Transmission (NALE Bit)

The RIIC has a function to cause arbitration to be lost if the internal SDA output level does not match the level on the SDA line (the 1 output as the internal SDA output; i.e. the SDA pin is in the high-impedance state) and the low level is detected on the SDA line during transmission of NACK in receive mode. Arbitration is lost due to a conflict of NACK transmission and ACK transmission when two or more master devices receive data from the same slave device simultaneously in a multi-master system. Such conflict occurs when multiple master devices send/receive the same information through a single slave device. Figure 24.34 shows an example of arbitration lost detection during transmission of NACK.

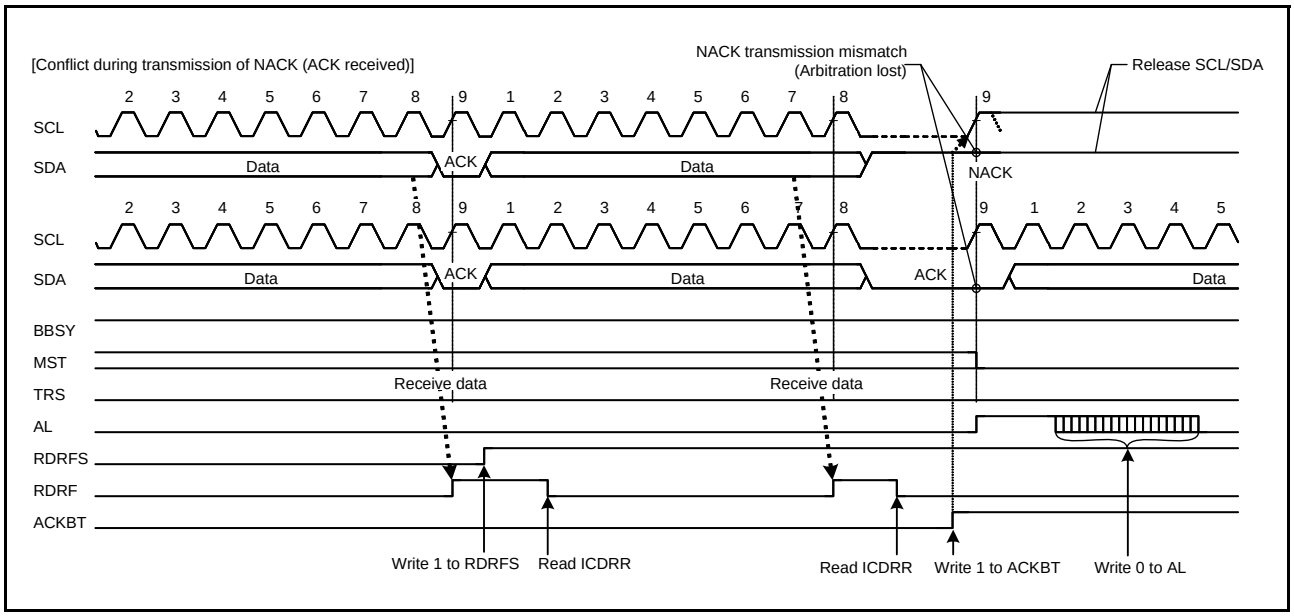


Figure 24.34 Example of Arbitration Lost Detection during Transmission of NACK (NALE = 1)

The following explains arbitration lost detection using an example where two master devices (master A and master B) and a single slave device are connected through the bus. In this example, master A receives two bytes of data from the slave device, and master B receives four bytes of data from the slave device.
If master A and master B access the slave device simultaneously, because the slave address is identical, arbitration is not lost in both master A and master B during access to the slave device. Therefore, both master A and master B recognize that they have obtained the bus mastership and operate as such. Here, master A sends NACK when it has received two final bytes of data from the slave device. Meanwhile, master B sends ACK because it has not received necessary four bytes of data. At this time, the NACK transmission from master A and the ACK transmission from master B conflict. In general, if a conflict like this occurs, master A cannot detect ACK transmitted by master B and issues a stop condition. Therefore, the issuance of the stop condition conflicts with the SCL clock output of master B, which disturbs communication.

When the RIIC receives ACK during transmission of NACK, it detects a defeat in conflict with other master devices and causes arbitration to be lost.

If arbitration is lost during transmission of NACK, the RIIC immediately cancels the slave match condition and enters slave receive mode. This prevents a stop condition from being issued, preventing a communication failure on the bus. Similarly, in the ARP command processing of SMBus, the function to detect loss of arbitration during transmission of NACK is also available for eliminating the extra clock cycle processing (such as FFh transmission processing) necessary if no response is received in the Get UDID (general) processing after the Assign address command.

The RIIC detects arbitration lost during transmission of NACK when the following condition is met with the NALE bit

in ICFER set to 1 (arbitration lost detection during NACK transmission enabled).

[Condition for arbitration lost during NACK transmission]

- When the internal SDA output level does not match the SDA line (ACK is received) during transmission of NACK (ACKBT bit = 1 in ICMR3)

24.9.3 Slave Arbitration Lost Detection (SALE Bit)

The RIIC has a function to cause arbitration to be lost if the data for transmission (i.e. the internal SDA output level) and the level on the SDA line do not match (the 1 output as the internal SDA output; i.e. the SDA pin is in the high-impedance state) and the low level is detected on the SDA line in slave transmitter mode. This arbitration lost detection function is mainly used when transmitting a UDID (Unique Device Identifier) over an SMBus.
When it loses slave arbitration, the RIIC is immediately released from the slave-matched state and enters slave receiver mode. This function can detect conflicts of data during transmission of UDIDs over an SMBus and eliminates subsequent redundant processing (processing for the transmission of FFh).
The RIIC detects slave arbitration lost when the following condition is met with the SALE bit in ICFER set to 1 (slave arbitration lost detection enabled).

[Condition for slave arbitration lost]

- When transmit data excluding acknowledge (internal SDA output level) does not match the SDA line in slave transmit mode (MST and TRS bits = 01b in ICCR2)

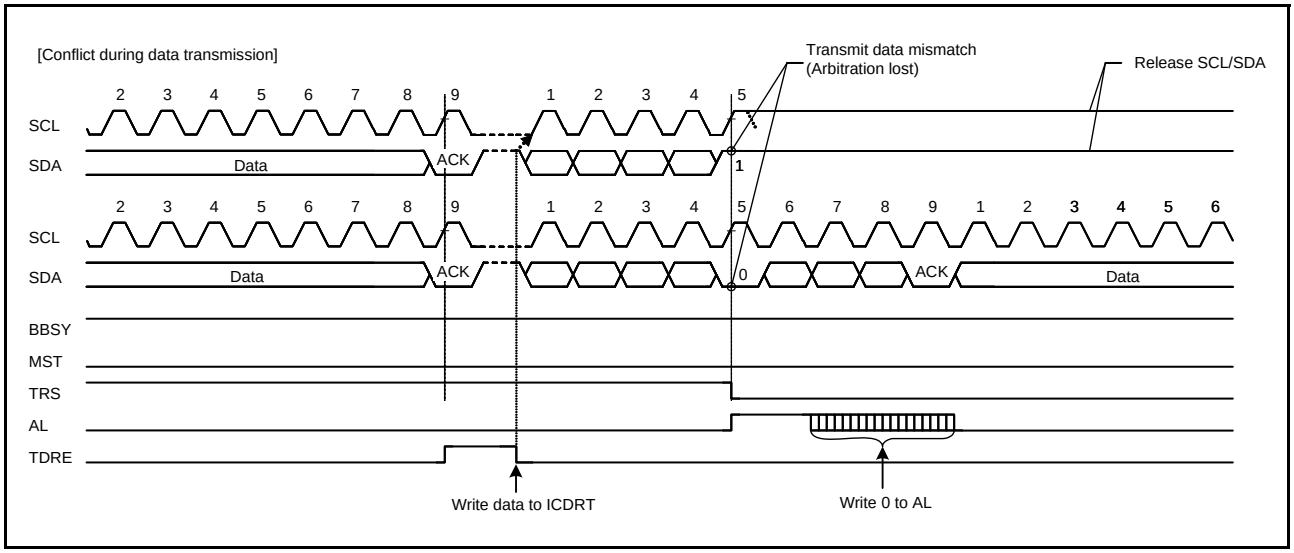


Figure 24.35 Example of Slave Arbitration Lost Detection (SALE = 1)

24.10 Start Condition/Restart Condition/Stop Condition Issuing Function

24.10.1 Issuing a Start Condition

The RIIC issues a start condition when the ST bit in ICCR2 is set to 1.
When the ST bit is set to 1, a start condition issuance request is made and the RIIC issues a start condition when the BBSY flag in ICCR2 is 0 (bus free). When a start condition is issued normally, the RIIC automatically shifts to the master transmit mode.
A start condition is issued in the following sequence.

[Start condition issuance]

- Drive the SDA line low (high level to low level).
- Ensure the time set in ICBRH and the start condition hold time.
- Drive the SCL line low (high level to low level).
- Detect low level of the SCL line and ensure the low-level period of SCL set in ICBRL.

24.10.2 Issuing a Restart Condition

The RIIC issues a restart condition when the RS bit in ICCR2 is set to 1.
When the RS bit is set to 1, a restart condition issuance request is made and the RIIC issues a restart condition when the BBSY flag in ICCR2 is 1 (bus busy) and the MST bit in ICCR2 is 1 (master mode).
A restart condition is issued in the following sequence.

[Restart condition issuance]

- Release the SDA line.
- Ensure the low-level period of SCL line set in ICBRL.
- Release the SCL line (low level to high level).
- Detect a high level of the SCL line and ensure the time set in ICBRL and the restart condition setup time.
- Drive the SDA line low (high level to low level).
- Ensure the time set in ICBRH and the restart condition hold time.
- Drive the SCL line low (high level to low level).
- Detect a low level of the SCL line and ensure the low-level period of SCL line set in ICBRL.

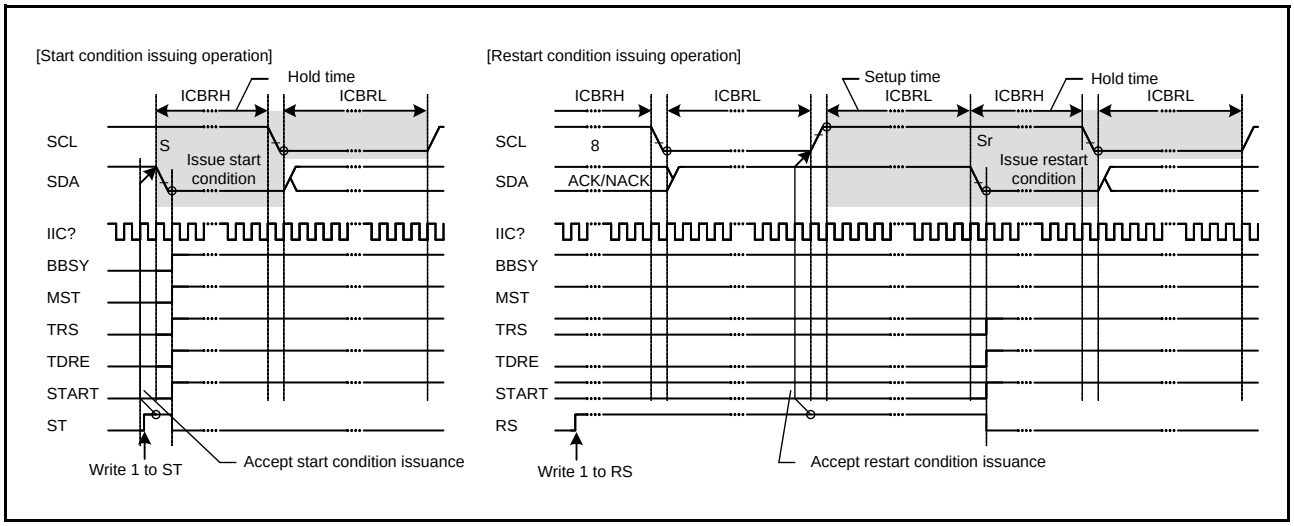


Figure 24.36 Start Condition/Restart Condition Issue Timing (ST and RS Bits)

24.10.3 Issuing a Stop Condition

The RIIC issues a stop condition when the SP bit in ICCR2 is set to 1.
When the SP bit is set to 1, a stop condition issuance request is made and the RIIC issues a stop condition when the BBSY flag in ICCR2 is 1 (bus busy) and the MST bit in ICCR2 is 1 (master mode).
A stop condition is issued in the following sequence.

[Stop condition issuance]

- Drive the SDA line low (high level to low level).
- Ensure the low-level period of SCL line set in ICBRL.
- Release the SCL line (low level to high level).
- Detect a high level of the SCL line and ensure the time set in ICBRH and the stop condition setup time.
- Release the SDA line (low level to high level).
- Ensure the time set in ICBRL and the bus free time.
- Clear the BBSY flag to 0 (to release the bus mastership).

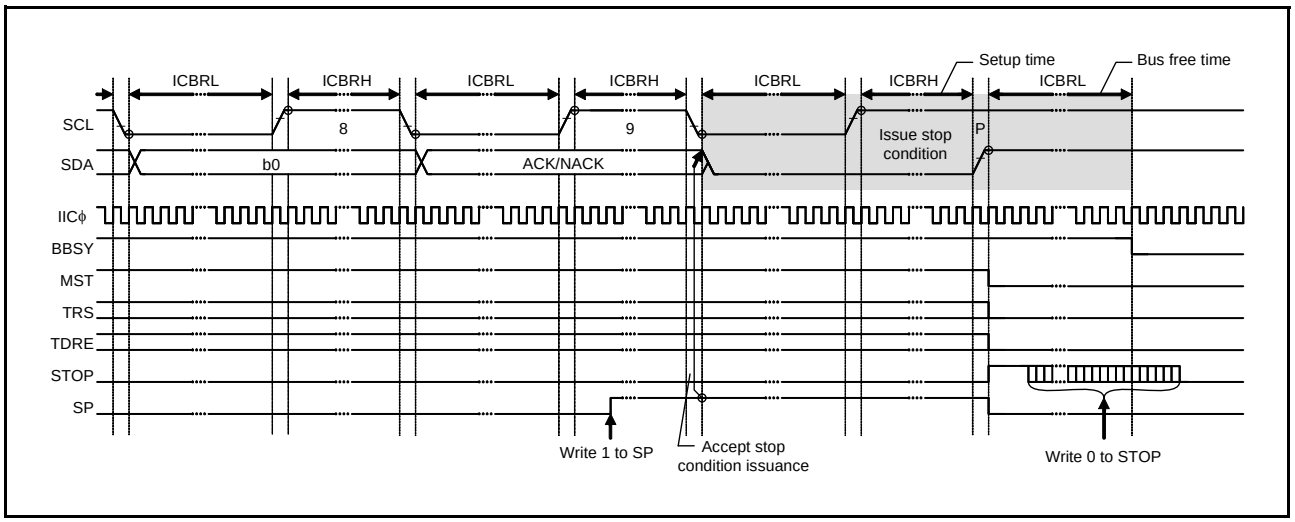


Figure 24.37 Stop Condition Issue Timing (SP Bit)

24.11 Bus Hanging

If the clock signals from the master and slave devices go out of synchronization due to noise or other factors, the I^2C bus might hang with a fixed level on the SCL line and/or SDA line.
As measures against the bus hanging, the RIIC has a timeout function to detect hanging by monitoring the SCL line, a function for the output of an extra SCL clock cycle to release the bus from a hung state due to clock signals being out of synchronization, and the RIIC/internal reset function.
By checking the SCLO, SDAO, SCLI, and SDAI bits in ICCR1, it is possible to see whether the RIIC or its partner in communications is placing the low level on the SCL or SDA lines.

24.11.1 Timeout Function

The RIIC has the timeout function to detect an abnormality that the SCL line is held for a certain period of time. In the bus busy state, the RIIC can detect an abnormal bus state by monitoring that the SCL line is held low or high for a predetermined time.
The timeout function monitors the SCL line state and counts the low-level period or high-level period using the internal counter. The timeout function resets the internal counter each time the SCL line changes (rising or falling), but continues to count unless the SCL line changes. If the internal counter overflows due to no SCL line change, the RIIC can detect the timeout and report the bus abnormality.
This timeout function is enabled when the TMOE bit in ICFER is 1. It detects an abnormal bus state that the SCL line is held low or high when the bus is busy (BBSY flag = 1 in ICCR2) in master mode or when the BBSY flag is 1 and the RIIC's own slave address matches (ICSR1 is not 00h) in slave mode.
The internal counter of the timeout function works using the internal reference clock (IICϕ) set by the CKS[2:0] bits in ICMR1 as a count source. It functions as a 16-bit counter when long mode is selected (TMOS bit = 0 in ICMR2) or a 14-bit counter when short mode is selected (TMOS bit = 1).
The SCL line level (low/high or both levels) during which this counter is activated can be selected by the setting of the TMOH and TMOL bits in ICMR2. If both TMOL and TMOH bits are cleared to 0, the internal counter does not work.

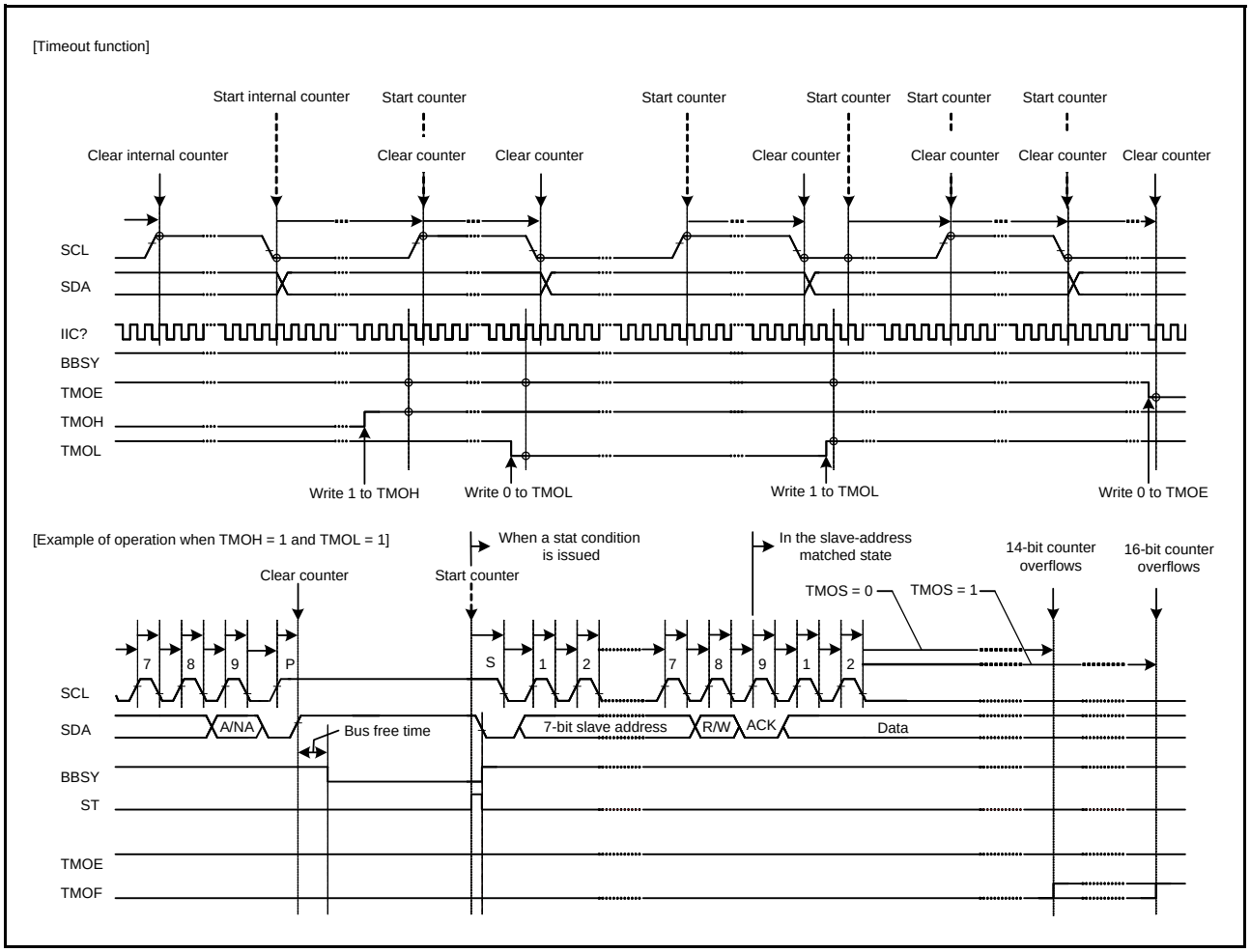


Figure 24.38 Timeout Function (TMOE, TMOS, TMOH, and TMOL Bits)

24.11.2 Extra SCL Clock Cycle Output Function

In master mode, the RIIC module has a facility for the output of extra SCL (clock) cycles to release the SDA line of the slave device from being held at the low level due to the master being out of synchronization with the slave device.
This function is mainly used in master mode to release the SDA line of the slave device from the state of being fixed to the low level by including extra cycles of SCL output from the RIIC with single cycles of the SCL (clock) signal as the unit in the case of a bus error where the RIIC cannot issue a stop condition because the slave device is holding the SDA line at the low level. Do not use this facility in normal situations. Using it when communications are proceeding correctly will lead to malfunctions.
When the CLO bit in ICCR1 is set to 1 in master mode, a single cycle of the SCL clock at the frequency corresponding to the transfer rate settings (settings of the CKS[2:0] bits in ICMR1, and of the ICBRH and ICBRL registers) is output as an extra clock cycle. After output of this single cycle of the SCL clock, the CLO bit is automatically cleared to 0. Therefore, further extra clock cycles can be output consecutively by the software program writing 1 to the CLO bit after having read CLO = 0.
When the RIIC module is in master mode and the slave device is holding the SDA line at the low level because synchronization with the slave device has been lost due to the effects of noise etc., the output of a stop condition is not possible. The facility for output of an extra cycle of the SCL (clock) signal can be used to output extra cycles of SCL one by one to make the slave device release the SDA line from being held at the low level, thus recovering the bus from an unusable state. Release of the SDA line by the slave device can be monitored by reading the SDAI bit in ICCR1. After confirming release of the SDA line by the slave device, complete communications by reissuing the stop condition.
Use this facility with the MALE bit (master arbitration lost detection disabled) in ICFER cleared to 0. If the MALE bit is set to 1 (master arbitration lost detection enabled), arbitration is lost when the value of the SDAO bit in ICCR1does not match the state of the SDA line, so take care on this point.

[Output conditions for using the CLO bit in ICCR1]

- When the bus is free (BBSY flag in ICCR2 = 0) or in master mode (MST bit = 1 and BBSY flag = 1 in ICCR2)
- When the communication device does not hold the SCL line low

Figure 24.39 shows the operation timing of the extra SCL clock cycle output function.

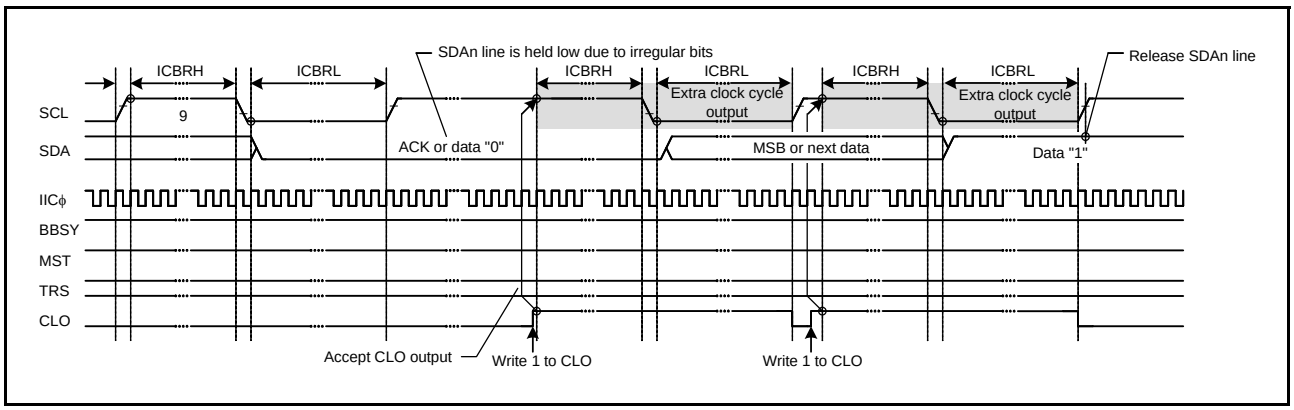


Figure 24.39 Extra SCL Clock Cycle Output Function (CLO Bit)

24.11.3 RIIC Reset and Internal Reset

The RIIC module incorporates a function for resetting itself. There are two types of reset. One is referred to as an RIIC reset; this initializes all registers including the BBSY flag in ICCR2. The other is referred to as an internal reset; this releases the RIIC from the slave-address matched state and initializes the internal counter while retaining other settings. After issuing a reset, be sure to clear the IICRST bit in ICCR1 to 0.

Both types of reset are effective for release from bus-hung states since both restore the output state of the SCL and SDA pins to the high impedance state.

Issuing a reset during slave operation may lead to a loss of synchronization between the master device clock and the slave device clock, so avoided this where possible. Note that monitoring of the bus state, such as for the presence of a start condition, is not possible during an RIIC reset (ICE and IICRST bits = 01b in ICCR1).

For a detailed description of the RIIC and internal resets, see section 24.14, Reset States.

24.12 SMBus Operation

The RIIC is available for data communication conforming to the SMBus standard (Version 2.0). To perform SMBus communication, set the SMBS bit in ICMR3 to 1 to select input level conforming to the SMBus for the SCL pin/SDA pin function. To use the transfer rate within a range of 10 kbps to 100 kbps of the SMBus standard, set the CKS[2:0] bits in ICMR1, ICBRH, and ICBRL. In addition, determine the values of the DLCS bit in ICMR2 and the SDDL[2:0] bits in ICMR2 to meet the data hold time specification of 300 ns or more. When the RIIC is used only as a slave device, the transfer rate setting is not necessary, whereas the ICBRL needs to be set to a value longer than the data setup time (250 ns).
For the SMBus device default address (1100 001b), use one of the slave address registers L0 to L2 (SARL0, SARL1, and SARL2), and set the corresponding FS bit (7-bit/10-bit address format select) in SARUy (y = 0 to 2) to 0 (7-bit address format).
When transmitting the UDID (Unique Device Identifier), set the SALE bit in ICFER to 1 to enable the slave arbitration lost detection function.

24.12.1 SMBus Timeout Measurement

(1) Measuring timeout of slave device

The following period (timeout interval: $T_{LOW:\ SEXT}$) must be measured for slave devices in SMBus communication.

- From start condition to stop condition

To measure timeout for slave devices, measure the period from start condition detection to stop condition detection with the on-chip timer using a start condition detection interrupt (STI) and stop condition detection interrupt (SPI) of the RIIC. The measured timeout period must be within the total clock low-level period [slave device] $T_{LOW:\ SEXT}$: 25 ms (max.) of the SMBus standard.
If the time measured with the on-chip timer exceeds the clock low-level detection timeout $T_{TIMEOUT}$: 25 ms (min.) of the SMBus standard, the slave device must release the bus by writing 1 to the IICRST bit in ICCR1 to issue an internal reset of the RIIC. When an internal reset is issued, the RIIC stops driving the bus for the SCL pin and SDA pin and make the SCL/SDA pin outputs high impedance, which releases the bus.

(2) Measuring timeout of master device

The following periods (timeout interval: $T_{LOW:\ MEXT}$) must be measured for master devices in SMBus communication.

- From start condition to acknowledge bit
- Between acknowledge bits
- From acknowledge bit to stop condition

To measure timeout for master devices, measure these periods with the on-chip timer using a start condition detection interrupt (STI), stop condition detection interrupt (SPI), and transmit end interrupt (ICTEI) or receive data full interrupt (ICRXI) of the RIIC. The measured timeout period must be within the total clock low-level extended period [master device] $T_{LOW:\ MEXT}$: 10 ms (max.) of the SMBus standard, and the total of all $T_{LOW:\ MEXT}$ from start condition to stop condition must be within $T_{LOW:\ SEXT}$: 25 ms (max.).

For the ACK receive timing (rising edge of the ninth SMBCLK clock cycle), monitor the TEND flag in ICSR2 in master transmit mode (master transmitter) and the RDRF flag in ICSR2 in master receive mode (master receiver). For this reason, perform bytewise transmit operation in master transmit mode, and hold the RDRFS bit in ICMR3 0 until the byte just before reception of the final byte in master receive mode. While the RDRFS bit is 0, the RDRF flag is set to 1 at the rising edge of the ninth SMBCLK clock cycle.

If the period measured with the on-chip timer exceeds the total clock low-level extended period [master device] $T_{LOW:\ MEXT}$: 10 ms (max.) of the SMBus standard or the total of measured periods exceeds the clock low-level detection timeout $T_{TIMEOUT}$: 25 ms (min.) of the SMBus standard, the master device must stop the transaction by issuing a stop condition. In master transmit mode, immediately stop the transmit operation (writing data to ICDRT).

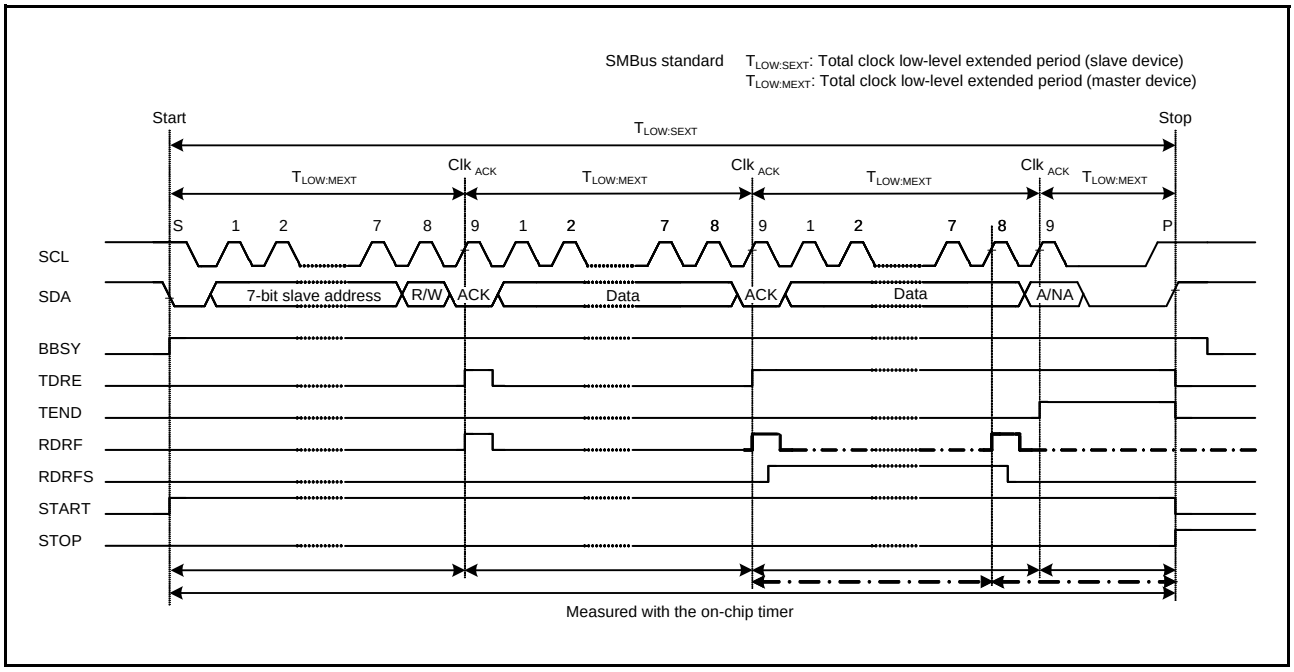


Figure 24.40 SMBus Timeout Measurement

24.12.2 Packet Error Code (PEC)

The RX62T Group incorporates a CRC operation circuit. The CRC operation circuit enables transmission of a packet error code (PEC) or checking the received data of the SMBus in data communication of the RIIC. For the CRC generating polynomials of the CRC operation circuit, see section 23, CRC Calculator (CRC).

The PEC data in master transmit mode (master transmitter) can be generated by writing all transmit data to the CRC data input register (CRCDIR) in the CRC operation circuit.

The REC data in master receive mode (master receiver) can be checked by writing all receive data to CRCDIR in the CRC operation circuit and comparing the obtained value in the CRC data output register (CRCDOR) with the received PEC data.

To send ACK or NACK according to the match or mismatch result when the final byte is received as a result of the PEC code check, set the RDRFS bit in ICMR3 to 1 before the rising edge of the eighth SMBCLK clock cycle during reception of the final byte, and hold the SCL line low at the falling edge of the eighth clock cycle.

24.12.3 SMBus Host Notification Protocol/Notify ARP Master

In communications over an SMBus, a slave device can temporarily act as a master device to notify the SMBus host (or ARP master) of (or request the SMBus host for) its own slave address or to request its own slave address from the SMBus host.

For a product of the RX62T Group to operate as an SMBus host (or ARP master), the host address (0001 000b) sent from the slave device must be detected as a slave address, so the RIIC has a function for detecting the host address. To detect the host address as a slave address, set the SMBS bit in ICMR3 and the HOAE bit in ICSER to 1. Operation after the host address has been detected is the same as normal slave operation.

24.13 Interrupt Sources

The RIIC issues four types of interrupt sources: transfer error or event generation (arbitration lost, NACK detection, timeout detection, start condition detection, and stop condition detection), receive data full, transmit data empty, and transmit end.

Table 24.7 shows details of the several interrupt sources. The receive data full and transmit data empty are both capable of launching data transfer by the DTC.

Table 24.7 Interrupt Sources

Abbreviation	Interrupt Source	Interrupt Flag	DTC Launching	Priority	Interrupt Condition
ICEEI0	Transfer Error/ Event Generation	AL	Not possible	High	(AL=1) • (ALIE=1)
		NACKF			(NACKF=1) • (NAKIE=1)
		TMOF			(TMOF=1) • (TMOIE=1)
		START			(START=1) • (STIE=1)
		STOP			(STOP=1) • (SPIE=1)
ICRXI0	Receive Data Full	—	Possible		(RDRF=1) • (RIE=1)
ICTXI0	Transmit Data Empty	—	Possible		(TDRE=1) • (TIE=1)
ICTEI0	Transmit End	TEND	Not possible	Low	(TEND=1) • (TEIE=1)

Clear or mask the various interrupt sources during interrupt handling.

Notes on interrupt processing:

1. There is a latency (delay) between the execution of a write instruction for a peripheral module by the CPU and actual writing to the module. Thus, when an interrupt flag has been cleared or masked, read the relevant flag again to check whether clearing or masking has been completed, and then return from interrupt processing. Returning from interrupt processing without checking that writing to the module has been completed creates a possibility of repeated processing of the same interrupt.
2. Since ICTXI is an edge-detected interrupted, it does not require clearing. Furthermore, the TDRE flag in ICSR2 (a condition for ICTXI) is automatically cleared to 0 when data for transmission are written to ICDRT or a stop condition is detected (STOP flag = 1 in ICSR2).
3. Since ICRXI is an edge-detected interrupted, it does not require clearing. Furthermore, the RDRF flag in ICSR2 (a condition for ICRXI) is automatically cleared to 0 when data are read out from ICDRR.
4. When using the ICTEI interrupt, clear the TEND flag in ICSR2 in the ICTEI interrupt processing. Note that the TEND flag in ICSR2 is automatically cleared to 0 when data for transmission are written to ICDRT or a stop condition is detected (STOP flag = 1 in ICSR2).

24.14 Reset States

The RIIC has chip reset, RIIC reset, and internal reset functions. Table 24.8 shows the scope of each reset and reset conditions.

Table 24.8 Reset Conditions

		Chip Reset	RIIC Reset (ICE = 0, IICRST = 1)	Internal Reset (ICE = 1, IICRST = 1)	Start Condition/ Restart Condition Detection	Stop Condition Detection
ICCR1	ICE, IICRST	At a reset	Retained	Retained	Operation (retained)	Operation (retained)
	SCLO, SDAO		At a reset	At a reset		
	Others			Retained		
ICCR2	BBSY	At a reset	At a reset	Operation	Operation	Operation
	ST			At a reset	At a reset	Operation (retained)
	Others					At a reset
ICMR1	BC[2:0]	At a reset	At a reset	At a reset	At a reset	Operation (retained)
	Others			Retained	Operation (retained)	
ICMR2		At a reset	At a reset	Retained	Operation (retained)	Operation (retained)
ICMR3		At a reset	At a reset	Retained	Operation (retained)	Operation (retained)
ICFER		At a reset	At a reset	Retained	Operation (retained)	Operation (retained)
ICSER		At a reset	At a reset	Retained	Operation (retained)	Operation (retained)
ICIER		At a reset	At a reset	Retained	Operation (retained)	Operation (retained)
ICSR1		At a reset	At a reset	At a reset	Operation (retained)	At a reset
ICSR2	TDRE, TEND	At a reset	At a reset	At a reset	Operation (retained)	At a reset
	START				Operation	
	STOP				Operation (retained)	Operation
	Others					Operation (retained)
SARL0 to SARL2 SARU0 to SARU2		At a reset	At a reset	Retained	Operation (retained)	Operation (retained)
ICBRH, ICBRL		At a reset	At a reset	Retained	Operation (retained)	Operation (retained)
ICDRT		At a reset	At a reset	Retained	Operation (retained)	Operation (retained)
ICDRR		At a reset	At a reset	Retained	Operation (retained)	Operation (retained)
ICDRS		At a reset	At a reset	At a reset	Operation (retained)	Operation (retained)
Timeout function		At a reset	At a reset	Operation	Operation	Operation
Bus free time measurement		At a reset	At a reset	Operation	Operation	Operation

24.15 Usage Notes

24.15.1 Setting Module Stop Function

Module stop state can be entered or canceled using module stop control register B (MSTPCRB). The initial setting is for operation of the RIIC to be halted. RIIC register access is enabled by clearing module stop state.
For details of module stop control register B, see section 9, Low Power Consumption.

24.15.2 Setting Input Buffer Control Register

Input to peripheral modules can be enabled or disabled using the input buffer control register (PORTn.ICR). The initial setting is for input to the RIIC to be disabled.
As the SCL and SDA lines on the I^2C bus are bidirectional, the SCL and SDA pins of the RIIC are input/output pins. Make appropriate settings in the input buffer control bits in the PORTn.ICR corresponding to the SCL and SDA pins of the RIIC to enable input to the RIIC. If the required input is disabled, the RIIC cannot detect start conditions (including restart conditions) or stop conditions, or count the SCL clock cycles.
For details of the input buffer control register, see section 15, I/O Ports.

25. CAN Module

25.1 Overview

The RX62T Group implements one channel of the CAN (Controller Area Network) module that complies with the ISO11898-1 Specifications. The CAN module transmits and receives both formats of messages, namely the standard identifier (11 bits) (identifier is hereafter referred to as ID) and extended ID (29 bits).
Table 25.1 lists the specifications of the CAN module, and Figure 25.1 shows a block diagram of the CAN module. Connect the CAN bus transceiver externally.

Note: • The CAN module is an optional function. For details, see Table 1.3.

Table 25.1 Specifications of CAN Module

Item	Description
Protocol	• ISO11898-1 compliant (standard and extended frames)
Bit rate	• Programmable bit rate up to 1 Mbps (fCAN ≥ 8 MHz) fCAN: CAN clock source
Message box	• 32 mailboxes: Two selectable mailbox modes Normal mailbox mode: 32 mailboxes can be configured for either transmission or reception. FIFO mailbox mode: 24 mailboxes can be configured for either transmission or reception. Of the other mailboxes, four FIFO stages can be configured for transmission and four FIFO stages for reception.
Reception	• Data frame and remote frame can be received. • Selectable receiving ID format (only standard ID, only extended ID, or both IDs) • Programmable one-shot reception function • Selectable from overwrite mode (message overwritten) and overrun mode (message discarded) • The reception complete interrupt can be individually enabled or disabled for each mailbox.
Acceptance filter	• Eight acceptance masks (one mask for every four mailboxes) • The mask can be individually enabled or disabled for each mailbox.
Transmission	• Data frame and remote frame can be transmitted. • Selectable transmitting ID format (only standard ID, only extended ID, or both IDs) • Programmable one-shot transmission function • Selectable from ID priority mode and mailbox number priority mode • Transmission request can be aborted (the completion of abort can be confirmed with a flag) • The transmission complete interrupt can be individually enabled or disabled for each mailbox.
Mode transition for bus-off recovery	• Mode transition for the recovery from the bus-off state can be selected: • ISO11898-1 Specifications compliant • Automatic entry to CAN halt mode at bus-off entry • Automatic entry to CAN halt mode at bus-off end • Entry to CAN halt mode by a program • Transition into error-active state by a program
Error status monitoring	• CAN bus errors (stuff error, form error, ACK error, CRC error, bit error, and ACK delimiter error) can be monitored. • Transition to error states can be detected (error-warning, error-passive, bus-off entry, and bus-off recovery). • The error counters can be read.
Time stamp function	• Time stamp function using a 16-bit counter • The reference clock can be selected from 1-, 2-, 4- and 8-bit time periods.
Interrupt function	• Five types of interrupt sources (reception complete, transmission complete, receive FIFO, transmit FIFO, and error interrupts)
CAN sleep mode	• Current consumption can be reduced by stopping the CAN clock.
Software support unit	• Three software support units: • Acceptance filter support • Mailbox search support (receive mailbox search, transmit mailbox search, and message lost search) • Channel search support
CAN clock source	• Peripheral module clock (PCLK)
Test mode	• Three test modes available for user evaluation Listen-only mode Self-test mode 0 (external loopback) Self-test mode 1 (internal loopback)

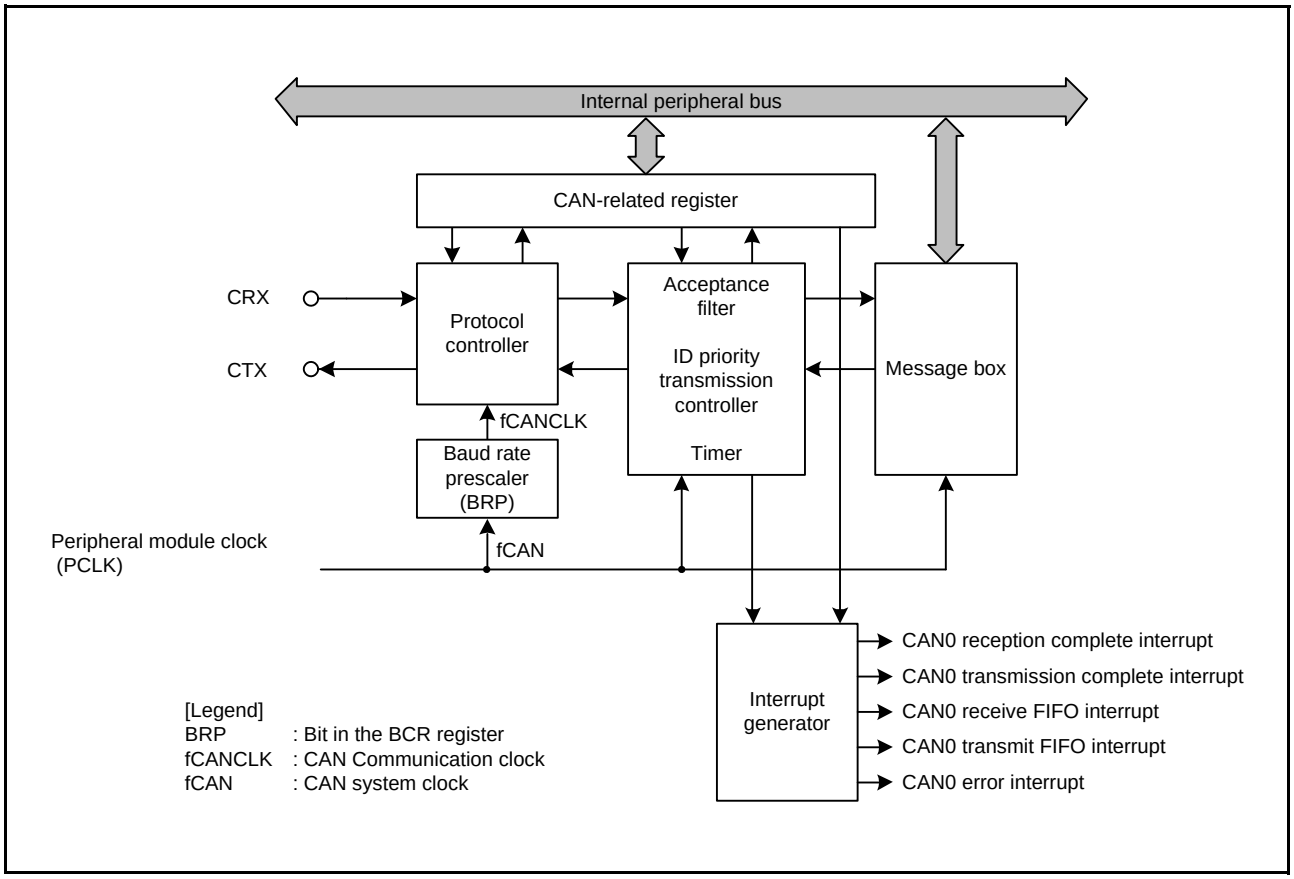


Figure 25.1 Block Diagram of CAN Module

- CRX and CTX
  CAN input and output pins
- Protocol controller
  Handles CAN protocol processing such as bus arbitration, bit timing at transmission and reception, stuffing, and error handling, etc.
- Message box
  Consists of 32 mailboxes which can be configured as either transmit or receive mailboxes. Each mailbox has an individual ID, data length code, a data field (8 bytes), and a time stamp.
- Acceptance filter
  Performs filtering of received messages. MKR0 to MKR7 are used for the filtering process.
- Timer
  Used for the time stamp function. The timer value when a message is stored into the mailbox is written as the time stamp value.
- Interrupt generator
  Generates the following five types of interrupts:
  CAN0 reception complete interrupt
  CAN0 transmission complete interrupt
  CAN0 receive FIFO interrupt
  CAN0 transmit FIFO interrupt
  CAN0 error interrupt

Table 25.2 shows the CAN module pins.
The CAN functions should be selected for the pins multiplexed with other signals. For details, see section 15, I/O Ports.

Table 25.2 Pin Configuration

Module Symbol	Pin Name	I/O	Function
CAN0	CRX	Input	Pin for receiving data
	CTX	Output	Pin for transmitting data

25.2 Register Descriptions

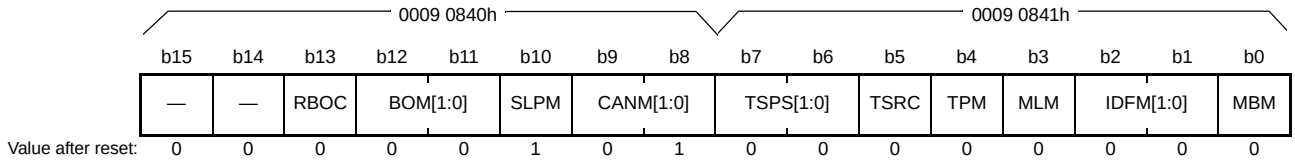
Table 25.3 lists the registers of the CAN module.

Table 25.3 Registers of CAN Module

Module Symbol	Register Name	Symbol	Value after Reset	Address	Access Size
CAN0	Control register	CTLR	0500h	0009 0840h	8, 16
	Bit configuration register	BCR	0000 0000h	0009 0844h	8, 16, 32
	Bit configuration register 0	MKR0	Undefined	0009 0400h	8, 16, 32
	Bit configuration register 1	MKR1	Undefined	0009 0404h	8, 16, 32
	Bit configuration register 2	MKR2	Undefined	0009 0408h	8, 16, 32
	Bit configuration register 3	MKR3	Undefined	0009 040Ch	8, 16, 32
	Bit configuration register 4	MKR4	Undefined	0009 0410h	8, 16, 32
	Bit configuration register 5	MKR5	Undefined	0009 0414h	8, 16, 32
	Bit configuration register 6	MKR6	Undefined	0009 0418h	8, 16, 32
	Bit configuration register 7	MKR7	Undefined	0009 041Ch	8, 16, 32
	FIFO received ID compare register 0	FIDCR0	Undefined	0009 0420h	8, 16, 32
	FIFO received ID compare register 1	FIDCR1	Undefined	0009 0424h	8, 16, 32
	Mask invalid register	MKIVLR	Undefined	0009 0428h	8, 16, 32
	Mailbox registers 0 to 31	MB0 to MB31	Undefined	0009 0200h to 0009 03FFh	8, 16, 32
	Mailbox interrupt enable register	MIER	Undefined	0009 042Ch	8, 16, 32
	Message control registers 0 to 31	MCTL0 to MCTL31	00h	0009 0820h to 0009 083Fh	8
	Receive FIFO control register	RFCR	80h	0009 0848h	8
	Receive FIFO pointer control register	RFPCR	Undefined	0009 0849h	8
	Transmit FIFO control register	TFCR	80h	0009 084Ah	8
	Transmit FIFO pointer control register	TFPCR	Undefined	0009 084Bh	8
	Status register	STR	0500h	0009 0842h	8, 16
	Mailbox search mode register	MSMR	00h	0009 0853h	8
	Mailbox search status register	MSSR	80h	0009 0852h	8
	Channel search support register	CSSR	Undefined	0009 0851h	8
	Acceptance filter support register	AFSR	Undefined	0009 0856h	8, 16
	Error interrupt enable register	EIER	00h	0009 084Ch	8
	Error interrupt factor judge register	EIFR	00h	0009 084Dh	8
	Receive error count register	RECR	00h	0009 084Eh	8
	Transmit error count register	TECR	00h	0009 084Fh	8
	Error code store register	ECSR	00h	0009 0850h	8
	Time stamp register	TSR	0000h	0009 0854h	8, 16
	Test control register	TCR	00h	0009 0858h	8

25.2.1 Control Register (CTLR)

Address: 0009 0840h



Bit	Symbol	Bit Name	Description	R/W
b0	MBM	CAN Mailbox Mode Select*1	0: Normal mailbox mode 1: FIFO mailbox mode	R/W
b2, b1	IDFM[1:0]	ID Format Mode Select*1	b2 b1 0 0: Standard ID mode All mailboxes (including FIFO mailboxes) handle only standard Ids. 0 1: Extended ID mode All mailboxes (including FIFO mailboxes) handle only extended IDs. 1 0: Mixed ID mode All mailboxes (including FIFO mailboxes) handle both standard IDs and extended IDs. Standard IDs or extended IDs are specified by using the IDE bit in the corresponding mailbox in normal mailbox mode. In FIFO mailbox mode, the IDE bit in the corresponding mailbox is used for mailboxes [0] to [23], the IDE bits in FIDCR0 and FIDCR1 are used for the receive FIFO, and the IDE bit in mailbox [24] is used for the transmit FIFO. 1 1: Do not use this combination	R/W
b3	MLM	Message Lost Mode Select*2	0: Overwrite mode 1: Overrun mode	R/W
b4	TPM	Transmission Priority Mode Select*2	0: ID priority transmit mode 1: Mailbox number priority transmit mode	R/W
b5	TSRC	Time Stamp Counter Reset Command*4	0: Nothing occurred 1: Reset*3	R/W
b7, b6	TSPS[1:0]	Time Stamp Prescaler Select*1	b7 b6 0 0: Every bit time 0 1: Every 2-bit time 1 0: Every 4-bit time 1 1: Every 8-bit time	R/W
b9, b8	CANM[1:0]	CAN Operating Mode Select*5	b9 b8 0 0: CAN operation mode 0 1: CAN reset mode 1 0: CAN halt mode 1 1: CAN reset mode (forcible transition)	R/W
b10	SLPM	CAN Sleep Mode*5*6	0: Other than CAN sleep mode 1: CAN sleep mode	R/W
b12, b11	BOM[1:0]	Bus-Off Recovery Mode*1	b12 b11 0 0: Normal mode (ISO11898-1 compliant) 0 1: Entry to CAN halt mode automatically at bus-off entry 1 0: Entry to CAN halt mode automatically at bus-off end 1 1: Entry to CAN halt mode (during bus-off recovery period) by a program request	R/W
b13	RBOC	Forcible Return From Bus-Off*2	0: Nothing occurred 1: Forcible return from bus-off*3	R/W
b15, b14	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

Note 1. Write to the BOM[1:0], TSPS[1:0], TPM, MLM, IDFM[1:0], and MBM bits in CAN reset mode.
Note 2. Set the RBOC bit to 1 in the bus-off state.
Note 3. This bit is automatically set back to 0 after being set to 1. It should be read as 0.
Note 4. Set the TSRC bit to 1 in CAN operation mode.
Note 5. When the CANM[1:0] and SLPM bits are changed, check STR to ensure that the mode has been switched. Do not change the CANM[1:0] bits or SLPM bit until the mode has been switched.
Note 6. Write to the SLPM bit in CAN reset mode or CAN halt mode. To change the value of the SLPM bit to 0 or 1, use an arithmetic/logic instruction to clear or set the bit.

MBM Bit (CAN Mailbox Mode Select)

When the MBM bit is 0 (normal mailbox mode), mailboxes [0] to [31] are configured as transmit or receive mailboxes.
When the MBM bit is 1 (FIFO mailbox mode), mailboxes [0] to [23] are configured as transmit or receive mailboxes. Mailboxes [24] to [27] are configured as a transmit FIFO and mailboxes [28] to [31] as a receive FIFO.
Transmit data is written into mailbox [24] (mailbox [24] is a window mailbox for the transmit FIFO). Receive data is read from mailbox [28] (mailbox [28] is a window mailbox for the receive FIFO).
Table 25.4 lists the mailbox configuration.

IDFM[1:0] Bits (ID Format Mode Select)

The IDFM[1:0] bits specify the ID format.

MLM Bit (Message Lost Mode Select)

The MLM bit specifies the operation when a new message is captured in the unread mailbox. Overwrite mode or overrun mode can be selected. All mailboxes (including the receive FIFO) are set to either overwrite mode or overrun mode.
When the MLM bit is 0, all mailboxes are set to overwrite mode and the new message is overwriting the old message.
When the MLM bit is 1, all mailboxes are set to overrun mode and the new message is discarded.

TPM Bit (Transmission Priority Mode Select)

The TPM bit specifies the priority of modes when transmitting messages. ID priority transmit mode or mailbox number transmit mode can be selected. All mailboxes are set for either ID priority transmission or mailbox number priority transmission.
When the TPM bit is 0, ID priority transmit mode is selected and transmission priority complies with the CAN bus arbitration rule, as defined in the ISO11898-1 Specifications. In ID priority transmit mode, mailboxes [0] to [31] (in normal mailbox mode), and mailboxes [0] to [23] (in FIFO mailbox mode), and the transmit FIFO are compared for the IDs of mailboxes configured for transmission. If two or more mailbox IDs are the same, the mailbox with the smaller number has higher priority.
Only the next message to be transmitted from the transmit FIFO is included in the transmission arbitration. If a transmit FIFO message is being transmitted, the next pending message within the transmit FIFO is included in the transmission arbitration.
When the TPM bit is 1, mailbox number transmit mode is selected and the transmit mailbox with the smallest mailbox number has the highest priority. In FIFO mailbox mode, the transmit FIFO has lower priority than normal mailboxes (mailboxes [0] to [23]).

TSRC Bit (Time Stamp Counter Reset Command)

The TSRC bit is used to reset the time stamp counter. When the TSRC bit is set to 1, TSR is set to 0000h. Then this bit is automatically set to 0.

TSPS[1:0] Bits (Time Stamp Prescaler Select)

The TSPS bits select the prescaler for the time stamp. The reference clock for the time stamp can be selected to be either 1-, 2-, 4- or 8-bit time periods.

CANM[1:0] Bits (CAN Operating Mode Select)

The CANM[1:0] bits select one of the following modes for the CAN module: CAN operation mode, CAN reset mode, or CAN halt mode. CAN sleep mode is set by the SLPM bit. For details, refer to section 25.3, Operating Mode.
When the CAN module enters CAN halt mode according to the setting of the BOM[1:0] bits, the CANM[1:0] bits are automatically set to 10.

SLPM Bit (CAN Sleep Mode)

When the SLPM bit is set to 1, the CAN module enters CAN sleep mode. When the SLPM bit is set to 0, the CAN module exits CAN sleep mode. For details, refer to section 25.3, Operating Mode.

BOM[1:0] Bits (Bus-Off Recovery Mode)

The BOM[1:0] bits are used to select bus-off recovery mode for the CAN module.
When the BOM[1:0] bits are 00b, the recovery from bus-off is compliant with the ISO11898-1 Specifications, i.e. the CAN module re-enters CAN communication (error-active state) after detecting 11 consecutive recessive bits 128 times. A bus-off recovery interrupt request is generated when recovering from bus-off.
When the BOM[1:0] bits are 01b, the CAN module enters CAN halt mode as soon as it reaches the bus-off state and the CANM[1:0] bits are set to 10b (CAN halt mode). No bus-off recovery interrupt request is generated when recovering from bus-off, and TECR and RECR are set to 00h.
When the BOM[1:0] bits are 10b, the CANM[1:0] bits are set to 10b as soon as the CAN module reaches the bus-off state. The CAN module enters CAN halt mode after the recovery from the bus-off state, i.e. after detecting 11 consecutive recessive bits 128 times. A bus-off recovery interrupt request is generated when recovering from bus-off, and TECR and RECR are set to 00h.
When the BOM[1:0] bits are 11b, the CAN module enters CAN halt mode by setting the CANM[1:0] bits to 10b while the CAN module is still in the bus-off state. No bus-off recovery interrupt request is generated when recovering from bus-off and TECR and RECR are set to 00h. However, if the CAN module recovers from bus-off after detecting 11 consecutive recessive bits 128 times before the CANM[1:0] bits are set to 10b, a bus-off recovery interrupt request is generated.
If the CPU requests an entry to CAN reset mode at the same time as the CAN module attempts to enter CAN halt mode (at bus-off entry when the BOM[1:0] bits are 01b, or at bus-off end when the BOM[1:0] bits are 10b), then the CPU request to enter CAN reset mode has higher priority.

RBOC Bit (Forcible Return From Bus-Off)

When the RBOC bit is set to 1 (force return from bus-off) in the bus-off state, the CAN module forcibly returns from the bus-off state. Then this bit is automatically set to 0. The error state changes from bus-off to error-active. When the RBOC bit is set to 1, RECR and TECR are set to 00h and the BOST bit in STR is set to 0 (the CAN module is not in bus-off state). The other registers remain unchanged even when the RBOC bit is set to 1. No bus-off recovery interrupt request is generated by this recovery from the bus-off state. Use the RBOC bit only when the BOM[1:0] bits are 00b (normal mode).

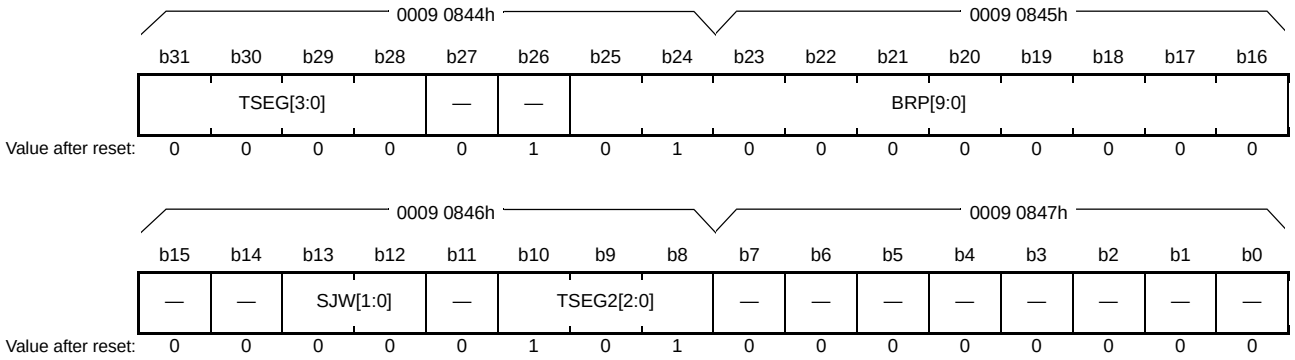
Table 25.4 Mailbox Configuration

Mailbox	MBM Bit = 0 (Normal Mailbox Mode)	MBM Bit = 1 (FIFO Mailbox Mode)
Mailboxes [0] to [23]	Normal mailbox	Normal mailbox
Mailboxes [24] to [27]		Transmit FIFO
Mailboxes [28] to [31]		Receive FIFO

Note: • Points 1 to 5 below should be considered when the CTLR.MBM bit is set to 1.
1. Transmit FIFO is controlled by TFCR. MCTLj (j = 0 to 31) of mailboxes [24] to [27] is disabled. MCTL24 to MCTL27 cannot be used by the transmit FIFO.
2. Receive FIFO is controlled by RFCR. MCTLj (j = 0 to 31) of mailboxes [28] to [31] is disabled. MCTL28 to MCTL31 cannot be used by the receive FIFO.
3. Refer to MIER about the FIFO interrupts.
4. The corresponding bits in MKIVLR for mailboxes [24] to [31] are disabled. Set 0 to these bits.
5. Transmit/receive FIFOs can be used for both data frames and remote frames.

25.2.2 Bit Configuration Register (BCR)

Address: 0009 0844h



Bit	Symbol	Bit Name	Description	R/W
b7 to b0	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b10 to b8	TSEG2[2:0]	Time Segment 2 Control	b10 b9 b8 0 0 0: Setting prohibited 0 0 1: 2 Tq 0 1 0: 3 Tq 0 1 1: 4 Tq 1 0 0: 5 Tq 1 0 1: 6 Tq 1 1 0: 7 Tq 1 1 1: 8 Tq	R/W
b11	—	Reserved	This bit is always read as 0.The write value should always be 0.	R/W
b13, b12	SJW[1:0]	Resynchronization Jump Width Control	b13 b12 0 0: 1Tq 0 1: 2Tq 1 0: 3Tq 1 1: 4Tq	R/W
b15, b14	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b25 to b16	BRP[9:0]	Prescaler Division Ratio Select	These bits set the frequency of the CAN communication clock (fCANCLK).	R/W
b27, b26	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b31 to 28	TSEG[3:0]	Time Segment 1 Control	b31 b28 0 0 0 0: Setting prohibited 0 0 0 1: Setting prohibited 0 0 1 0: Setting prohibited 0 0 1 1: 4 Tq 0 1 0 0: 5 Tq 0 1 0 1: 6 Tq 0 1 1 0: 7 Tq 0 1 1 1: 8 Tq 1 0 0 0: 9 Tq 1 0 0 1: 10 Tq 1 0 1 0: 11 Tq 1 0 1 1: 12 Tq 1 1 0 0: 13 Tq 1 1 0 1: 14 Tq 1 1 1 0: 15 Tq 1 1 1 1: 16 Tq	R/W

Tq: Time Quantum

BCR specifies the segment length with a Tq value.
For bit timing setting, refer to section 25.4, CAN Communication Speed Setting.
Set BCR before entering CAN halt mode or CAN operation mode from CAN reset mode. After the setting is made once, this register can be written to in CAN reset mode or CAN halt mode.
BCR consists of 24 bits. A 32-bit read/write access should be performed carefully not to rewrite bits b0 to b7.

TSEG2[2:0] Bits (Time Segment 2 Control)

The TSEG2[2:0] bits are used to specify the length of the phase buffer segment 2 (PHASE_SEG2) with a Tq value. A value from 2 to 8 Tq can be set. Set a value smaller than that of the TSEG1[3:0] bits.

SJW[1:0] Bits (Resynchronization Jump Width Control)

The SJW[1:0] bits are used to specify the resynchronization jump width with a Tq value. A value from 1 to 4 Tq can be set. Set a value smaller than or equal to that of the TSEG2[2:0] bits.

BRP[9:0] Bits (Prescaler Division Ratio Select)

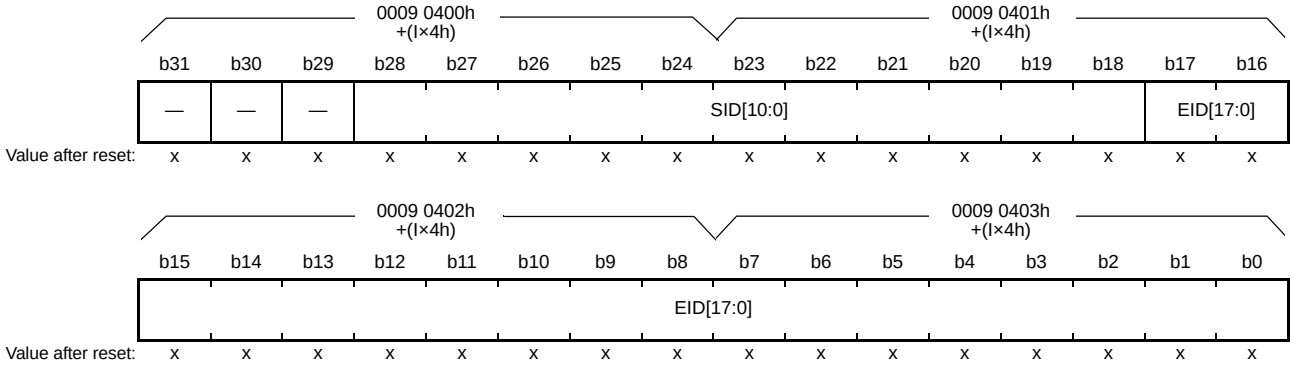
The BRP[9:0] bits are used to set the frequency of the CAN communication clock (fCANCLK). The fCANCLK cycle is 1 Tq. If the setting is P (0 to 1023), the baud rate prescaler divides fCAN by P + 1.

TSEG1[3:0] Bits (Time Segment 1 Control)

The TSEG1[3:0] bits are used to specify the total length of the propagation time segment (PROP_SEG) and phase buffer segment 1 (PHASE_SEG1) with a time quantum (Tq) value.
A value from 4 to 16 Tq can be set.

25.2.3 Mask Register i (MKRi) (i = 0 to 7)

Address: 0009 0400h to 0009 041Ch



[Legend] x: Undefined

Bit	Symbol	Bit Name	Description	R/W
b17 to b0	EID[17:0]	Extended ID	0: Corresponding EID[17:0] bit is not compared 1: Corresponding EID[17:0] bit is compared	R/W
b28 to b18	SID[10:0]	Standard ID	0: Corresponding SID[10:0] bit is not compared 1: Corresponding SID[10:0] bit is compared	R/W
b31 to b29	—	Reserved	The read value is undefined. The write value should always be 0.	R/W

For the mask function in FIFO mailbox mode, refer to section 25.6, Acceptance Filtering and Masking Functions.
Write to MKR0 to MKR7 in CAN reset mode or CAN halt mode.

EID Bit (Extended ID)

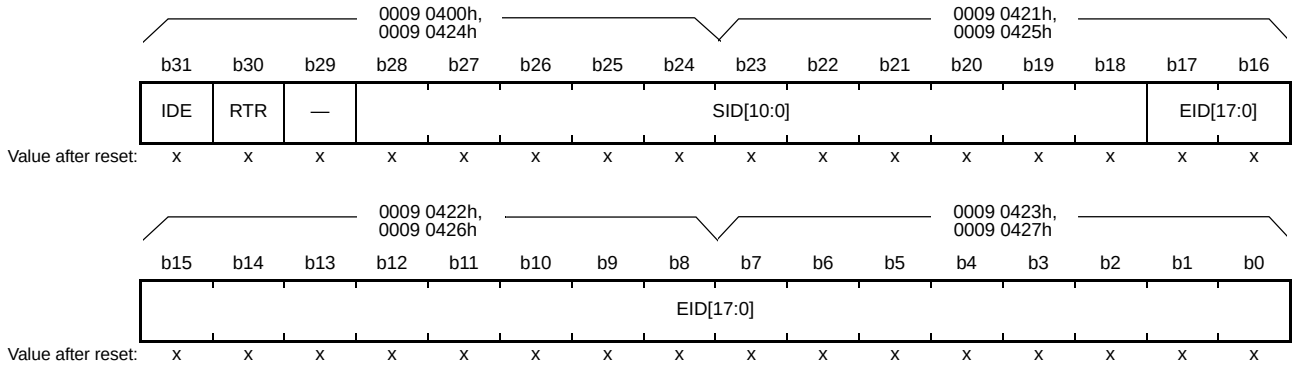
The EID[17:0] bits are the filter mask bits for the CAN extended ID bits.
These bits are used to receive extended ID messages.
When the EID[17:0] bit is set to 0, the received ID is not compared with the mailbox ID for the corresponding EID[17:0] bit.
When the EID[17:0] bit is set to 1, the received ID is compared with the mailbox ID for the corresponding EID[17:0] bit.

SID Bit (Standard ID)

The SID[10:0] bits are the filter mask bits corresponding to the CAN standard ID bits.
These bits are used to receive both standard ID and extended ID messages.
When the SID[10:0] bit is set to 0, the received ID is not compared with the mailbox ID for the corresponding SID[10:0] bit.
When the SID[10:0] bit is set to 1, the received ID is compared with the mailbox ID for the corresponding SID[10:0] bit.

25.2.4 FIFO Received ID Compare Registers 0 and 1 (FIDCR0 and FIDCR1)

Address: FIDCR1 0009 0420h,
FIDCR1 0009 0424h



[Legend] x: Undefined

Bit	Symbol	Bit Name	Description	R/W
b17 to b0	EID[17:0]	Extended ID	0: Corresponding EID[17:0] bit is 0 1: Corresponding EID[17:0] bit is 1	R/W
b28 to b18	SID[10:0]	Standard ID	0: Corresponding SID[10:0] bit is 0 1: Corresponding SID[10:0] bit is 1	R/W
b29	—	Reserved	The read value is undefined. The write value should always be 0.	R/W
b30	RTR	Remote Transmission Request	0: Data frame 1: Remote frame	R/W
b31	IDE	ID Extension*	0: Standard ID 1: Extended ID	R/W

Note 1. When the IDFM[1:0] bits in CTLR are not 10b, the IDE bit should be written with 0 and read as 0.

FIDCR0 and FIDCR1 are enabled when the MBM bit in CTLR is set to 1 (FIFO mailbox mode). Bits EID[17:0], SID[10:0], RTR, and IDE bits in MB28 to MB31 are disabled.
For the usage of FIDCR0 and FIDCR1, refer to section 25.6, Acceptance Filtering and Masking Functions.
Write to FIDCR0 and FIDCR1 in CAN reset mode or CAN halt mode.

EID Bit (Extended ID)

The EID[17:0] bits set the extended ID of data frames and remote frames.
The EID[17:0] bits are used to receive extended ID messages.

SID Bit (Standard ID)

The SID[10:0] bits set the standard ID of data frames and remote frames.
The SID[10:0] bits are used to receive both standard ID and extended ID messages.

RTR Bit (Remote Transmission Request)

The RTR bit sets the specified frame format of data frames or remote frames.

- When both RTR bits in FIDCR0 and FIDCR1 are set to 0, only data frames can be received.
- When both RTR bits in FIDCR0 and FIDCR1 are set to 1, only remote frames can be received.
- When the RTR bits in FIDCR0 and FIDCR1 are set to 0 or 1 individually, both data frames and remote frames can be received.

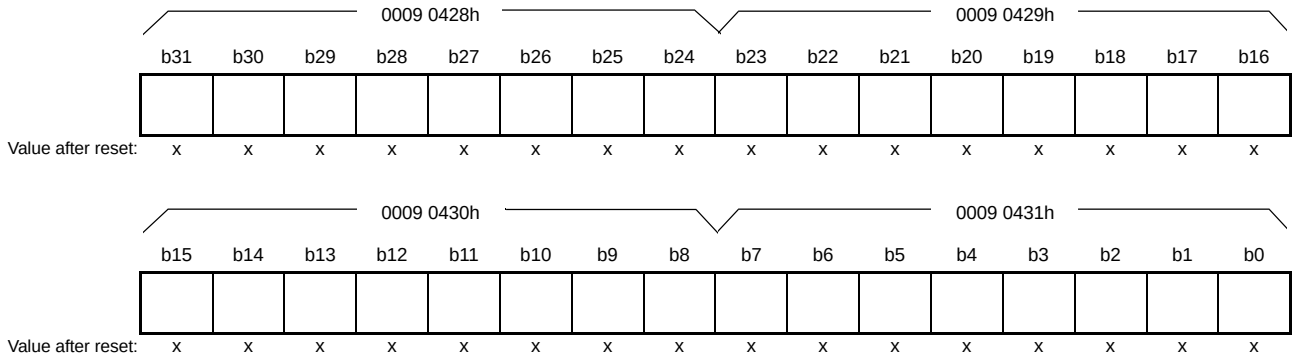
IDE Bit (ID Extension)

The IDE bit sets the ID format to standard ID or extended ID. The IDE bit is enabled when the IDFM[1:0] bits in CTLR is 10b (mixed ID mode).

- When both IDE bits in FIDCR0 and FIDCR1 are set to 0, only standard ID frames can be received.
- When both IDE bits in FIDCR0 and FIDCR1 are set to 1, only extended ID frames can be received.·
- When the IDE bits in FIDCR0 and FIDCR1 are set to 0 or 1 individually, both standard ID and extended ID frames can be received.

25.2.5 Mask Invalid Register (MKIVLR)

Address: 0009 0428h



[Legend] x: Undefined

Bit	Symbol	Bit Name	Description	R/W
b31 to b0	—	—	0: Mask valid 1: Mask invalid	R/W

Each bit in MKIVLR corresponds to a mailbox.
The correspondence between the bits and mailboxes is shown below.
Bit 0 in MKIVLR corresponds to mailbox 0 and bit 31 corresponds to mailbox 31.*
When a bit is set to 1, the relevant acceptance mask register becomes invalid for the corresponding mailbox. When a mask invalid bit is set to 1, a message is received by the corresponding mailbox only if the receive message ID matches the mailbox ID exactly.
Write to MKIVLR in CAN reset mode or CAN halt mode.

Note 1. Set bits 31 to 24 to 0 in FIFO mailbox mode.

25.2.6 Mailbox Register j (MBj) (j = 0 to 31)

Table 25.5 lists the CAN mailbox memory mapping, and Table 25.6 lists the CAN data frame configuration.
The value after reset of the CAN mailbox is undefined.
Write to MBj only when the related MCTLj (j = 0 to 31) is 00h and the corresponding mailbox is not processing an abort request.
See Table 25.3 for detailed register addresses.

Table 25.5 Mailbox Memory Mapping

Address CAN0	Register Symbol CAN0	Message Content Memory Mapping
0009 0200h + 16 x j + 0	MB.ID	IDE, RTR, SID10 to SID6
0009 0200h + 16 x j + 1		SID5to SID0, EID17, EID16
0009 0200h + 16 x j + 2		EID15 to EID8
0009 0200h + 16 x j + 3		EID7 to EID0
0009 0200h + 16 x j + 4	MB.DLC	—
0009 0200h + 16 x j + 5		Data length code (DLC[3:0])
0009 0200h + 16 x j + 6	MB.DATA0 to MB.DATA7	Data byte 0
0009 0200h + 16 x j + 7 : 0009 0200h + 16 x j + 13		Data byte 1 : Data byte 7
0009 0200h + 16 x j + 14	MB.TS	Time stamp upper byte
0009 0200h + 16 x j + 15		Time stamp lower byte

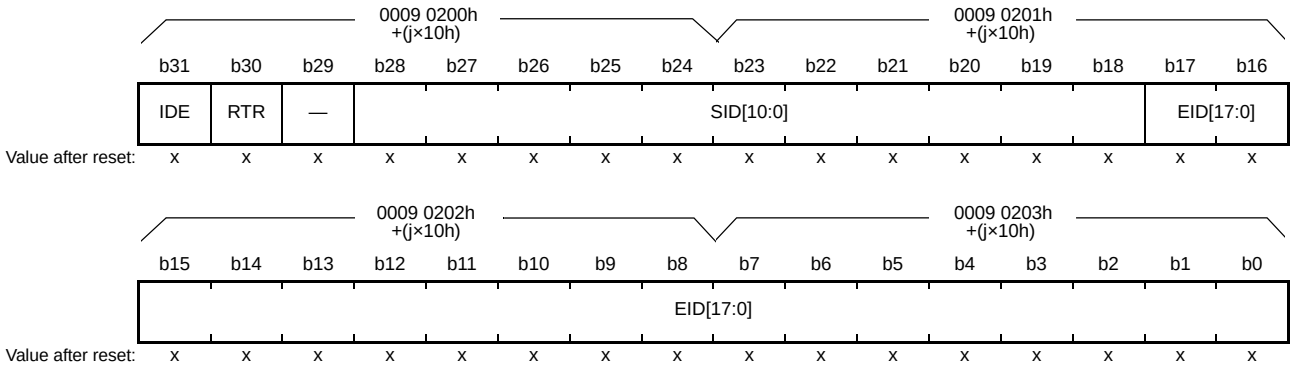
Table 25.6 CAN Data Frame Configuration

SID10 to SID6	SID5 to SID0	EID17 to EID16	EID15 to EID8	EID7 to EID0	DLC3 to DLC1	DATA0	DATA1	…	DATA7

The previous value of each mailbox is retained unless a new message is received.

(a) MB.ID

Address: 0009 0200h to 0009 03FFh



[Legend] x: Undefined

Bit	Symbol	Bit Name	Description	R/W
b17 to b0	EID[17:0]	Extended ID*1	0: Corresponding EID[17:0] bit is 0 1: Corresponding EID[17:0] bit is 1	R/W
b28 to b18	SID[10:0]	Standard ID	0: Corresponding SID[10:0] bit is 0 1: Corresponding SID[10:0] bit is 1	R/W
b29	—	Reserved	The read value is undefined. The write value should always be 0.	R/W
b30	RTR	Remote Frame Request	0: Data frame 1: Remote frame	R/W
b31	IDE	ID Extension*2	0: Standard ID 1: Extended ID	R/W

Note 1. If the mailbox has received a standard ID message, the EID[17:0] bits in the mailbox are undefined.
Note 2. The IDE bit is enabled when the IDFM[1:0] bits in CTLR are 10b (mixed ID mode). When the IDFM[1:0] bits in CTLR are not 10b, it should be written with 0 and read as 0.

EID[17:0] Bit (Extended ID)

The EID[17:0] bits set the extended ID of data frames and remote frames.

The EID[17:0] bits are used to transmit or receive extended ID messages.

SID[10:0] Bit (Standard ID)

The SID[10:0] bits set the standard ID of data frames and remote frames.

The SID[10:0] bits are used to transmit or receive both standard ID and extended ID messages.

RTR Bit (Remote Frame Request)

The RTR bit sets the frame format of data frames or remote frames.

- Receive mailbox receives only frames with the format specified by the RTR bit.·
- Transmit mailbox transmits according to the frame format specified by the RTR bit.
- Receive FIFO mailbox receives the data frame, remote frame, or both frames specified by the RTR bit in FIDCR0 and FIDCR1.
- Transmit FIFO mailbox transmits the data frame or remote frame specified by the RTR bit in the relevant transmit message.

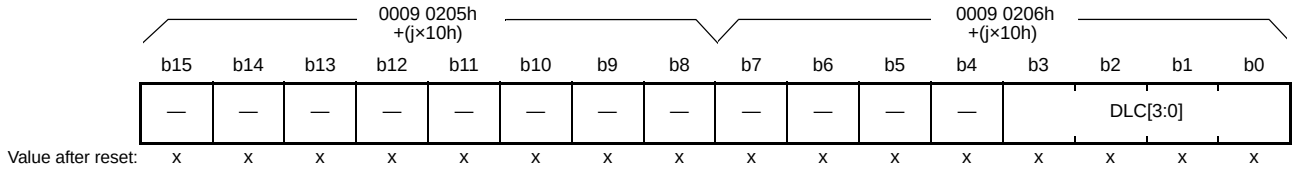
IDE Bit (ID Extension)

The IDE bit sets the ID format of standard IDs or extended IDs. The IDE bit is enabled when the IDFM[1:0] bits in CTLR is 10b (mixed ID mode).

- Receive mailbox receives only the ID format specified by the IDE bit.
- Transmit mailbox transmits with the ID format specified by the IDE bit.
- Receive FIFO mailbox receives messages with the standard ID, extended ID, or both IDs specified by the IDE bit in FIDCR0 and FIDCR1.
- Transmit FIFO mailbox transmits messages with the standard ID or extended ID specified by the IDE bit in the relevant transmit message.

(b) MB.DLC

Address: 0009 0205h to 0009 03F5h



[Legend] x: Undefined

Bit	Symbol	Bit Name	Description	R/W
b3 to b0	DLC[3:0]	Data Length Code*1	b3 b0 0 0 0 0: Data length = 0 byte 0 0 0 1: Data length = 1 byte 0 0 1 0: Data length = 2 bytes 0 0 1 1: Data length = 3 bytes 0 1 0 0: Data length = 4 bytes 0 1 0 1: Data length = 5 bytes 0 1 1 0: Data length = 6 bytes 0 1 1 1: Data length = 7 bytes 1 x x x: Data length = 8 bytes Note:x represents any value.	R/W
b15 to b4	—	Reserved	The read value is undefined. The write value should always be 0.	R/W

Note 1. If the mailbox has received a message whose data length set by the DLC[3:0] bits is less than 8 bytes, the values of DATA larger than the data length set by the DLC[3:0] bits in the mailbox are undefined.

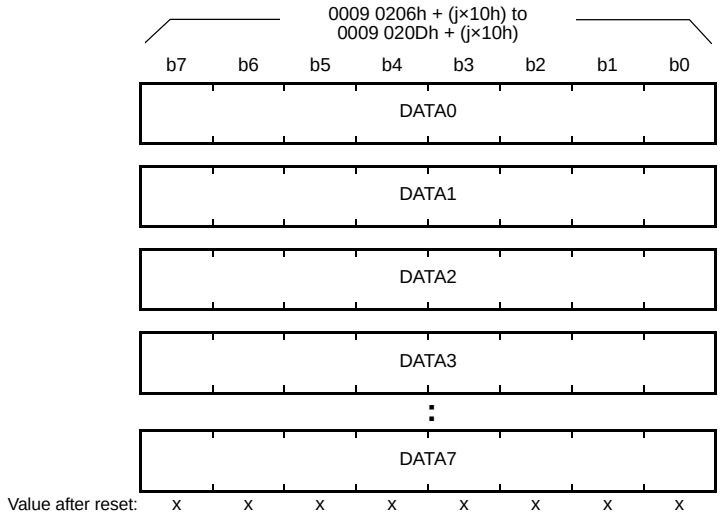
DLC[3:0] Bits (Data Length Code)

The DLC[3:0] bits are used to set the number of data bytes to be transmitted in a data frame. When data is requested using a remote frame, the number of data bytes to be requested is set.

When a data frame is received, the number of received data bytes is stored. When a remote frame is received, the number of requested data bytes is stored.

(c) MB.DATA0 to MB.DATA7

Address: 0009 0206h to 0009 03FDh



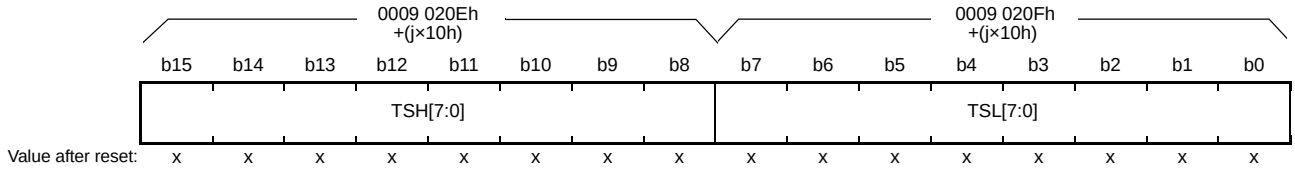
[Legend] x: Undefined

Bit	Symbol	Bit Name	Description	R/W
b7 to b0	DATA0 to DATA7	Data Bytes 0 to 7*1*2	DATA0 to DATA7 store the transmitted or received CAN message data. Transmission or reception starts from DATA0. The bit order on the CAN bus is MSB first, and transmission or reception starts from bit 7.	R/W

Note 1. If the mailbox has received a message with n bytes less than 8 bytes, the values of DATA0 to DATA7 in the mailbox are undefined.
Note 2. If the mailbox has received a remote frame, the previous values of DATA0 to DATA7 in the mailbox are retained.

(d) MB.TS

Address: 0009 020Eh to 0009 03FFh



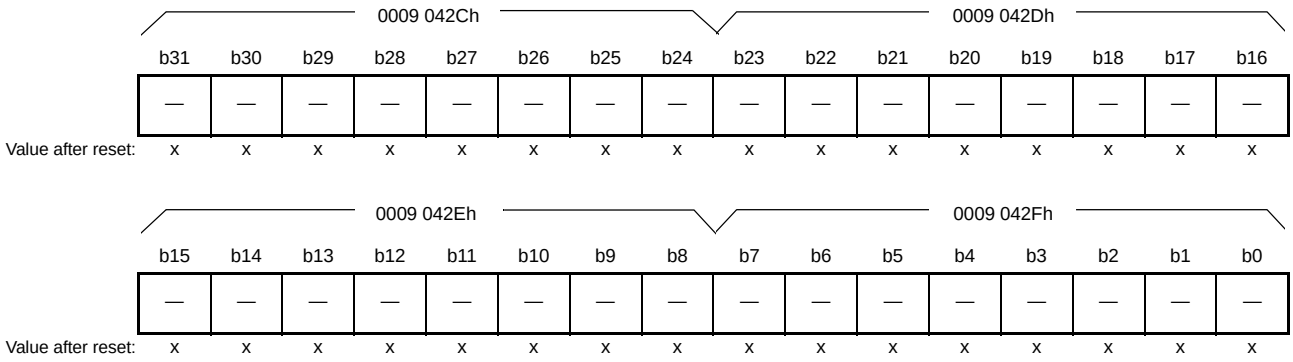
[Legend] x: Undefined

Bit	Symbol	Bit Name	Description	R/W
b7 to b0	TSL[7:0]]	Time Stamp Lower Byte	Bits TSH[7:0] and TSL[7:0] store the counter value of the time stamp when received messages are stored in the mailbox.	R/W
b15 to b8	TSH[7:0]	Time Stamp Higher Byte		R/W

25.2.7 Mailbox Interrupt Enable Register (MIER)

- Normal mailbox mode

Address: 0009 042Ch

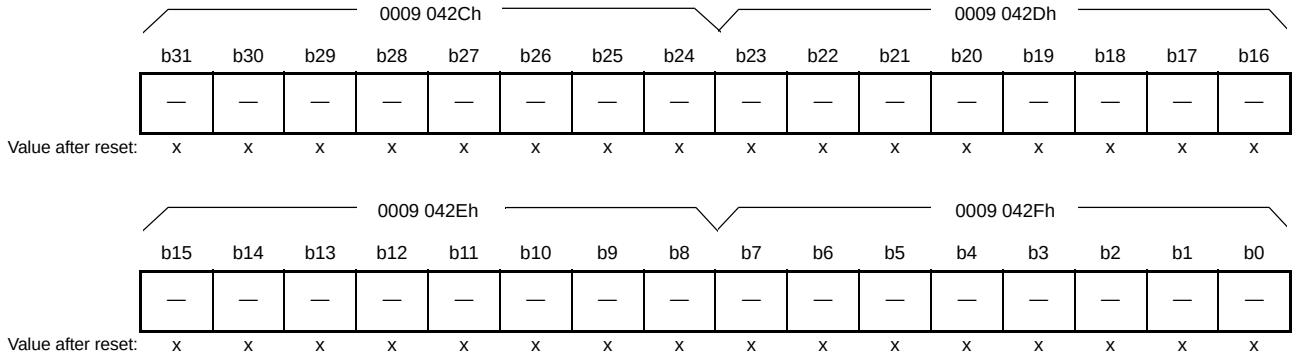


[Legend] x: Undefined

Bit	Symbol	Bit Name	Description	R/W
b31 to b0	—	Interrupt Enable	0: Interrupt disabled 1: Interrupt enabled Bit 31 corresponds to mailbox 31, and bit 0 corresponds to mailbox 0.	R/W

- FIFO mailbox mode

Address: 0009 042Ch



[Legend] x: Undefined

Bit	Symbol	Bit Name	Description	R/W
b23 to b0	—	Interrupt Enable	0: Interrupt disabled 1: Interrupt enabled Bit 23 corresponds to mailbox 23, and bit 0 corresponds to mailbox 0.	R/W
b24	—	Transmit FIFO Interrupt Enable	0: Interrupt disabled 1: Interrupt enabled	R/W
b25	—	Transmit FIFO Interrupt Generation Timing Control	0: Every time transmission is completed 1: When the transmit FIFO becomes empty due to completion of transmission	R/W
b27, b26	—	Reserved	The read value is undefined. The write value should always be 0.	R/W
b28	—	Receive FIFO Interrupt Enable	0: Interrupt disabled 1: Interrupt enabled	R/W
b29	—	Receive FIFO Interrupt Generation Timing Control*1	0: Every time reception is completed 1: When the receive FIFO becomes buffer warning by completion of reception	R/W
b31, b30	—	Reserved	The read value is undefined. The write value should always be 0.	R/W

Note 1. No interrupt request is generated when the receive FIFO becomes buffer warning from full. “Buffer warning” indicates a state in which the third message is stored in the receive FIFO.

MIER can individually enable interrupts for each mailbox.
In normal mailbox mode (all bits) and in FIFO mailbox mode (bits 23 to 0 in MIER), each bit corresponds to the mailbox with the related number. These bits enable or disable transmission/reception complete interrupts for the corresponding mailboxes.

- Bit 0 in MIER corresponds to mailbox 0.
- Bit 31 in MIER corresponds to mailbox 31.

In FIFO mailbox mode, bits 29, 28, 25, and 24 of MIER specify whether transmit/receive FIFO interrupts are enabled/disabled and the timing when interrupt requests are generated.
Write to MIER only when the related MCTLj (j = 0 to 31) is 00h and the corresponding mailbox is not processing a transmission or reception abort request. In FIFO mailbox mode, change the bits in MIER for the related FIFO only when the TFE bit in TFCR is 0 and the TFEST bit in TFCR is 1, and the RFE bit in RFCR is 0 and the RFEST bit in RFCR is 1.

25.2.8 Message Control Register j (MCTLj) (j = 0 to 31)

Address: 0009 0820h to 0009 083Fh

- MCTL.TX
  Transmit mode (when the TRMREQ bit is 1 and the RECREQ bit is 0)

	b7	b6	b5	b4	b3	b2	b1	b0
	TRMREQ	RECREQ	—	ONESHOT	—	TRMABT	TRMACTIVE	SENTDATA
Value after reset:	0	0	0	0	0	0	0	0

- MCTL.RX
  Receive mode (when the TRMREQ bit is 0 and the RECREQ bit is 1)

	b7	b6	b5	b4	b3	b2	b1	b0
	TRMREQ	RECREQ	—	ONESHOT	—	MSGLOST	INVALDATA	NEWDATA
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	SENTDATA	Transmission Complete Flag*1*2	0: Transmission is not completed 1: Transmission is completed	R/W (W)
	NEWDATA	Reception Complete Flag*1*2	0: No data has been received or 0 is written to the NEWDATA bit 1: A new message is being stored or has been stored to the mailbox	R/W (W)
b1	TRMACTIVE	Transmission-in-Progress Status Flag	(Transmit mailbox setting enabled) 0: Transmission is pending or transmission is not requested 1: From acceptance of transmission request to completion of transmission, or error/arbitration lost	R
	INVALDATA	Reception-in-Progress Status Flag	(Receive mailbox setting enabled) 0: Message valid 1: Message being updated	R
b2	TRMABT	Transmission Abort Complete Flag *1*2	(Transmit mailbox setting enabled) 0: Transmission has started, transmission abort failed because transmission is completed, or transmission abort is not requested 1: Transmission abort is completed	R/W (W)
	MSGLOST	Message Lost Flag*1*2	(Receive mailbox setting enabled) 0: Message is not overwritten or overrun 1: Message is overwritten or overrun	R/W (W)
b3	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b4	ONESHOT	One-Shot Enable*3	0: One-shot reception or one-shot transmission disabled 1: One-shot reception or one-shot transmission enabled	R/W
b5	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b6	RECREQ	Receive Mailbox Request*2*3*4*5	0: Not configured for reception 1: Configured for reception	R/W
b7	TRMREQ	Transmit Mailbox Request*2*4	0: Not configured for transmission 1: Configured for transmission	R/W

Note 1. Write 0 only. Writing 1 has no effect.
Note 2. When writing 0 to bits NEWDATA, SENTDATA, MSGLOST, TRMABT, RECREQ, and TRMREQ by a program, do not use the logic operation instruction (AND.B). Write 0 to only the specified bit and write 1 to the other bits before using the transfer (MOV) instruction. Writing 1 to this bit has no effect.
Note 3. To enter one-shot receive mode, write 1 to the ONESHOT bit at the same time as setting the RECREQ bit to 1.
To exit one-shot receive mode, write 0 to the ONESHOT bit after writing 0 to the RECREQ bit and confirming that it has been set to 0.
To enter one-shot transmit mode, write 1 to the ONESHOT bit at the same time as setting the TRMREQ bit to 1.
To exit one-shot transmit mode, write 0 to the ONESHOT bit after the message has been transmitted or aborted.
Note 4. Do not set both the RECREQ and TRMREQ bits to 1.
Note 5. When setting the RECREQ bit to 0, set bits MSGLOST, NEWDATA, and RECREQ to 0 simultaneously.

Write to the MCTLj in CAN operation mode or CAN halt mode.
Do not use MCTL24 to MCTL31 in FIFO mailbox mode.

SENTDATA Flag (Transmission Complete Flag)

The SENTDATA flag is set to 1 when data transmission from the corresponding mailbox is completed. The SENTDATA flag is set to 0 by writing 0 by a program.
To set the SENTDATA flag to 0, first set the TRMREQ bit to 0. Bits SENTDATA and TRMREQ cannot be set to 0 simultaneously. To transmit a new message from the corresponding mailbox, set the SENTDATA flag to 0.

NEWTDATA Flag (Reception Complete Flag)

The NEWDATA flag is set to 1 when a new message is being stored or has been stored to the mailbox. The timing for setting this bit to 1 is simultaneous with the INVALDATA bit. The NEWDATA flag is set to 0 by writing 0 by a program. The NEWDATA flag cannot be set to 0 by writing 0 by a program while the related INVALDATA bit is 1.

TRMACTIVE Bit (Transmission-in-Progress Status Flag)

The TRMACTIVE bit is set to 1 when the corresponding mailbox of the CAN module begins transmitting a message. The TRMACTIVE is set to 0 when the CAN module has lost CAN bus arbitration, a CAN bus error occurs, or data transmission is completed.

INVALDATA Bit (Reception-in-Progress Status Flag)

After the completion of a message reception, the INVALDATA bit is set to 1 while the received message is being updated into the corresponding mailbox. The INVALDATA bit is set to 0 immediately after the message has been stored. If the mailbox is read while the INVALDATA bit is 1, the data is undefined.

TRMABT Flag (Transmission Abort Complete Flag)

The TRMABT flag is set to 1 in the following cases:

- Following a transmission abort request, when the transmission abort is completed before starting transmission.·
- Following a transmission abort request, when the CAN module detects CAN bus arbitration lost or a CAN bus error.
- In one-shot transmission mode (RECREQ bit = 0, TRMREQ bit = 1, and ONESHOT bit = 1), when the CAN module detects CAN bus arbitration lost or a CAN bus error.

The TRMABT flag is not set to 1 when data transmission is completed. In this case, the SENTDATA flag is set to 1. The TRMABT flag is set to 0 by writing 0 by a program.

MSGLOST Flag (Message Lost Flag)

The MSGLOST flag is set to 1 when the mailbox is overwritten or overrun by a new received message while the NEWDATA flag is 1. The MSGLOST flag is set to 1 at the end of the 6th bit of EOF. The MSGLOST flag is set to 0 by writing 0 by a program.
In both overwrite and overrun modes, the MSGLOST flag cannot be set to 0 by writing 0 by a program during five peripheral module clock (PCLK) cycles following the sixth bit of EOF.

ONESHOT Bit (One-Shot Enable)

The ONESHOT bit can be used in the following two ways, receive mode and transmit mode.

- One-shot receive mode

  When the ONESHOT bit is set to 1 in receive mode (RECREQ bit = 1 and TRMREQ bit = 0), the mailbox receives a message only one time. (The mailbox does not behave as a receive mailbox after having received a message one time.) The behavior of bits NEWDATA and INVALDATA is the same as in normal receive mode. In one-shot receive mode, the MSGLOST flag is not set to 1.To set the ONESHOT bit to 0, first write 0 to the RECREQ bit and ensure that it has been set to 0.

- One-shot transmit mode

  When the ONESHOT bit is set to 1 in transmit mode (RECREQ bit = 0 and TRMREQ bit = 1), the CAN module transmits a message only one time. (The CAN module does not transmit the message again if a CAN bus error or CAN bus arbitration lost occurs.) When transmission is completed, the SENTDATA flag is set to 1. If transmission is not completed due to a CAN bus error or CAN bus arbitration lost, the TRMABT flag is set to 1. Set the ONESHOT bit to 0 after the SENTDATA or TRMABT bit is set to 1.

RECREQ Bit (Receive Mailbox Request)

The RECREQ bit selects receive modes shown in Table 25.11.
When the RECREQ bit is set to 1, the corresponding mailbox is configured for reception of a data frame or a remote frame.
When the RECREQ bit is set to 0, the corresponding mailbox is not configured for reception of a data frame or a remote frame.
Due to hardware protection, the RECREQ bit cannot be set to 0 by writing 0 by a program during the following period.

- Hardware protection is started

  From the acceptance filter processing (the beginning of CRC field)

- Hardware protection is released
  - For the mailbox that is specified to receive the incoming message, after the received data is stored into the mailbox or a CAN bus error occurs (i.e. maximum period of hardware protection is from the beginning of CRC field to the end of the 7th bit of EOF)
  - For the other mailboxes, after the acceptance filter processing
  - If no mailbox is specified to receive the message, after the acceptance filter processing
    When setting the RECREQ bit to 1, do not set the TRMREQ bit to 1. To change the configuration of a mailbox from transmission to reception, first abort the transmission and then set bits SENTDATA and TRMABT to 0 before changing to reception.

When setting the RECREQ bit to 1, do not set the TRMREQ bit to 1. To change the configuration of a mailbox from transmission to reception, first abort the transmission and then set bits SENTDATA and TRMABT to 0 before changing to reception.

TRMREQ Bit (Transmit Mailbox Request)

The TRMREQ bit selects transmit modes shown in Table 25.11.

When the TRMREQ bit is set to 1, the corresponding mailbox is configured for transmission of a data frame or a remote frame.

When the TRMREQ bit is set to 0, the corresponding mailbox is not configured for transmission of a data frame or a remote frame.

If the TRMREQ bit is changed from 1 to 0 to cancel the corresponding transmission request, either the TRMABT or SENTDATA flag is set to 1 with a maximum delay of one frame. This is used to confirm whether the transmission abort request has been completed or not. When setting the TRMREQ bit to 1, do not set the RECREQ bit to 1. To change the configuration of a mailbox from reception to transmission, first abort the reception and then set bits NEWDATA and MSGLOST to 0 before changing to transmission.

25.2.9 Receive FIFO Control Register (RFCR)

Address: 0009 0848h

	b7	b6	b5	b4	b3	b2	b1	b0
	RFEST	RFWST	RFFST	RFMLF	RFUST[2:0]			RFE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	RFE	Receive FIFO Enable	0: Receive FIFO disabled 1: Receive FIFO enabled	R/W
b3 to b1	RFUST[2:0]	Receive FIFO Unread Message Number Status	b3 b1 0 0 0: No unread message 0 0 1: 1 unread message 0 1 0: 2 unread messages 0 1 1: 3 unread messages 1 0 0: 4 unread messages 1 0 1: Reserved 1 1 0: Reserved 1 1 1: Reserved	R
b4	RFMLF	Receive FIFO Message Lost Flag	0: No receive FIFO message lost has occurred 1: Receive FIFO message lost has occurred	R/W
b5	RFFST	Receive FIFO Full Status Flag	0: Receive FIFO is not full 1: Receive FIFO is full (4 unread messages)	R
b6	RFWST	Receive FIFO Buffer Warning Status Flag	0: Receive FIFO is not buffer warning 1: Receive FIFO is buffer warning (3 unread messages)	R
b7	RFEST	Receive FIFO Empty Status Flag	0: Unread message in receive FIFO 1: No unread message in receive FIFO	R

Write to RFCR in CAN operation mode or CAN halt mode.

RFE Bit (Receive FIFO Enable)

When the RFE bit is set to 1, the receive FIFO is enabled.

When the RFE bit is set to 0, the receive FIFO is disabled for reception and becomes empty (RFEST bit = 1). Write 0 to the RFE bit simultaneously with setting the RFMLF bit.

Do not set this bit to 1 in normal mailbox mode (MBM bit in CTLR = 0). Due to hardware protection, the RFE bit is not set to 0 by writing 0 by a program during the following period.

- Hardware protection is started
  - From the acceptance filter processing (the beginning of CRC field)
- Hardware protection is released
  - If the receive FIFO is specified to receive the incoming message, after the received data is stored into the receive FIFO or a CAN bus error occurs (i.e. maximum period of hardware protection is from the beginning of CRC field to the end of 7th bit of EOF)
  - If the receive FIFO is not specified to receive the message, after the acceptance filter processing

RFUST[2:0] Bits (Receive FIFO Unread Message Number Status)

The RFUST[2:0] bits indicate the number of unread messages in the receive FIFO.

The value of the RFUST[2:0] bits is initialized to 000 when the RFE bit is set to 0.

RFMLF Flag (Receive FIFO Message Lost Flag)

The RFMLF bit is set to 1 (receive FIFO message lost has occurred) when the receive FIFO receives a new message and the receive FIFO is full. The timing for setting this bit to 1 is at the end of the 6th bit of EOF.
The RFMLF bit is set to 0 by writing 0 by a program (writing 1 has no effect). In both overwrite and overrun modes, the RFMLF bit cannot be set to 0 (receive FIFO message lost has not occurred) by writing 0 by a program due to hardware protection during five peripheral module clock (PCLK) cycles following the sixth bit of EOF, if the receive FIFO is full and determined to receive a message.

RFFST Flag (Receive FIFO Full Status Flag)

The RFFST bit is set to 1 (receive FIFO is full) when the number of unread messages in the receive FIFO is 4. The RFFST bit is 0 (receive FIFO is not full) when the number of unread messages in the receive FIFO is less than 4. The RFFST bit is set to 0 when the RFE bit is 0.

RFWST Flag (Receive FIFO Buffer Warning Status Flag)

The RFWST bit is set to 1 (receive FIFO is buffer warning) when the number of unread messages in the receive FIFO is 3. The RFWST bit is 0 (receive FIFO is not buffer warning) when the number of unread messages in the receive FIFO is less than 3 or equal to 4. The RFWST bit is set to 0 when the RFE bit is 0.

RFEST Flag (Receive FIFO Empty Status Flag)

The RFEST bit is set to 1 (no unread message in receive FIFO) when the number of unread messages in the receive FIFO is 0. The RFEST bit is set to 1 when the RFE bit is set to 0. The RFEST bit is set to 0 (unread message in receive FIFO) when the number of unread messages in the receive FIFO is one or more.

Table 25.2 shows the receive FIFO mailbox operation.

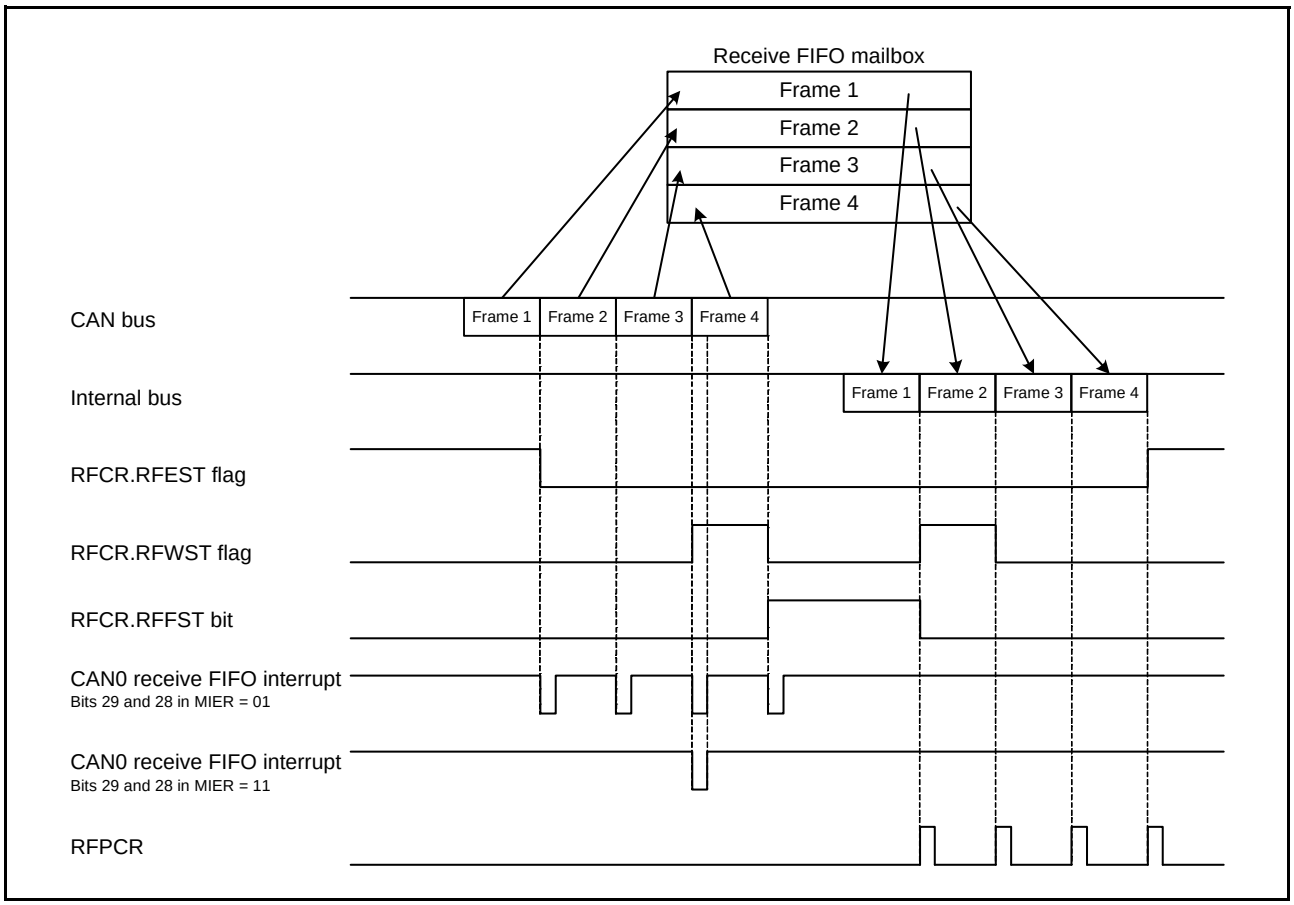


Figure 25.2 Receive FIFO Mailbox Operation (Bits 29 and 28 in MIER = 01 or 11)

25.2.10 Receive FIFO Pointer Control Register (RFPCR)

Address: 0009 0849h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—
Value after reset:	x	x	x	x	x	x	x	x

[Legend] x: Undefined

Bit	Symbol	Bit Name	Description	R/W
b7 to b0	—	—	The CPU-side pointer for the receive FIFO is incremented by writing FFh to RFPCR.	W

When the receive FIFO is not empty, write FFh to RFPCR by a program to increment the CPU-side pointer for the receive FIFO to the next mailbox location.
Do not write to RFPCR when the RFE bit in RFCR is 0 (receive FIFO disabled).
Both the CAN-side pointer and the CPU-side pointer are incremented when a new message is received and the RFFST bit in RFCR is 1 (receive FIFO is full) in overwrite mode. When the RFMLF bit in RFCR is 1 in this condition, the CPU-side pointer cannot be incremented by writing to RFPCR by a program.

25.2.11 FIFO Control Register (TFCR)

Address: 0009 084Ah

	b7	b6	b5	b4	b3	b2	b1	b0
	TFEST	TFFST	—	—	TFUST[2:0]			TFE
Value after reset:	1	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	TFE	Transmit FIFO Enable	0: Transmit FIFO disabled 1: Transmit FIFO enabled	R/W
b3 to b1	TFUST[2:0]	Transmit FIFO Unsent Message Number Status	b3 b1 000: No unsent message 001: 1 unsent message 010: 2 unsent messages 011: 3 unsent messages 100: 4 unsent messages 101: Reserved 110: Reserved 111: Reserved	R
b5, b4	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b6	TFFST	Transmit FIFO Full Status	0: Transmit FIFO is not full 1: Transmit FIFO is full (4 unsent messages)	R
b7	TFEST	Transmit FIFO Full Status	0: Unsent message in transmit FIFO 1: No unsent message in transmit FIFO	R

Write to TFCR in CAN operation mode or CAN halt mode.

TFE Bit (Transmit FIFO Enable)

When the TFE bit is set to 1, the transmit FIFO is enabled.
When the TFE bit is set to 0, the transmit FIFO becomes empty (TFEST bit = 1) and then unsent messages from the transmit FIFO are lost as described below:

- Immediately if a message from the transmit FIFO is not scheduled for the next transmission or during transmission
- Following the completion of transmission, a CAN bus error, CAN bus arbitration lost, or entry to CAN halt mode if a message from the transmit FIFO is scheduled for the next transmission or already during transmission

Before setting the TFE bit to 1 again, ensure that the TFEST bit has been set to 1. After setting the TFE bit to 1, write transmit data into MB24.
Do not set the TFE bit to 1 in normal mailbox mode (MBM bit in CTLR = 0).

TFUST[2:0] Bits (Transmit FIFO Unsent Message Number Status)

The TFUST[2:0] bits indicate the number of unsent messages in the transmit FIFO.
The TFUST[2:0] bits are set to 000 when transmission from the transmit FIFO has been aborted.

TFFST Bit (Transmit FIFO Full Status)

The TFFST bit is set to 1 (transmit FIFO is full) when the number of unsent messages in the transmit FIFO is 4. The TFFST bit is set to 0 (transmit FIFO is not full) when the number of unsent messages in the transmit FIFO is less than 4.
The TFFST bit is set to 0 when transmission from the transmit FIFO has been aborted.

TFEST Bit (Transmit FIFO Empty Status)

The TFEST bit is set to 1 (no message in transmit FIFO) when the number of unsent messages in the transmit FIFO is 0.
The TFEST bit is set to 1 when transmission from the transmit FIFO has been aborted. The TFEST bit is set to 0 (message in transmit FIFO) when the number of unsent messages in the transmit FIFO is not 0.

Table 25.3 shows the transmit FIFO mailbox operation.

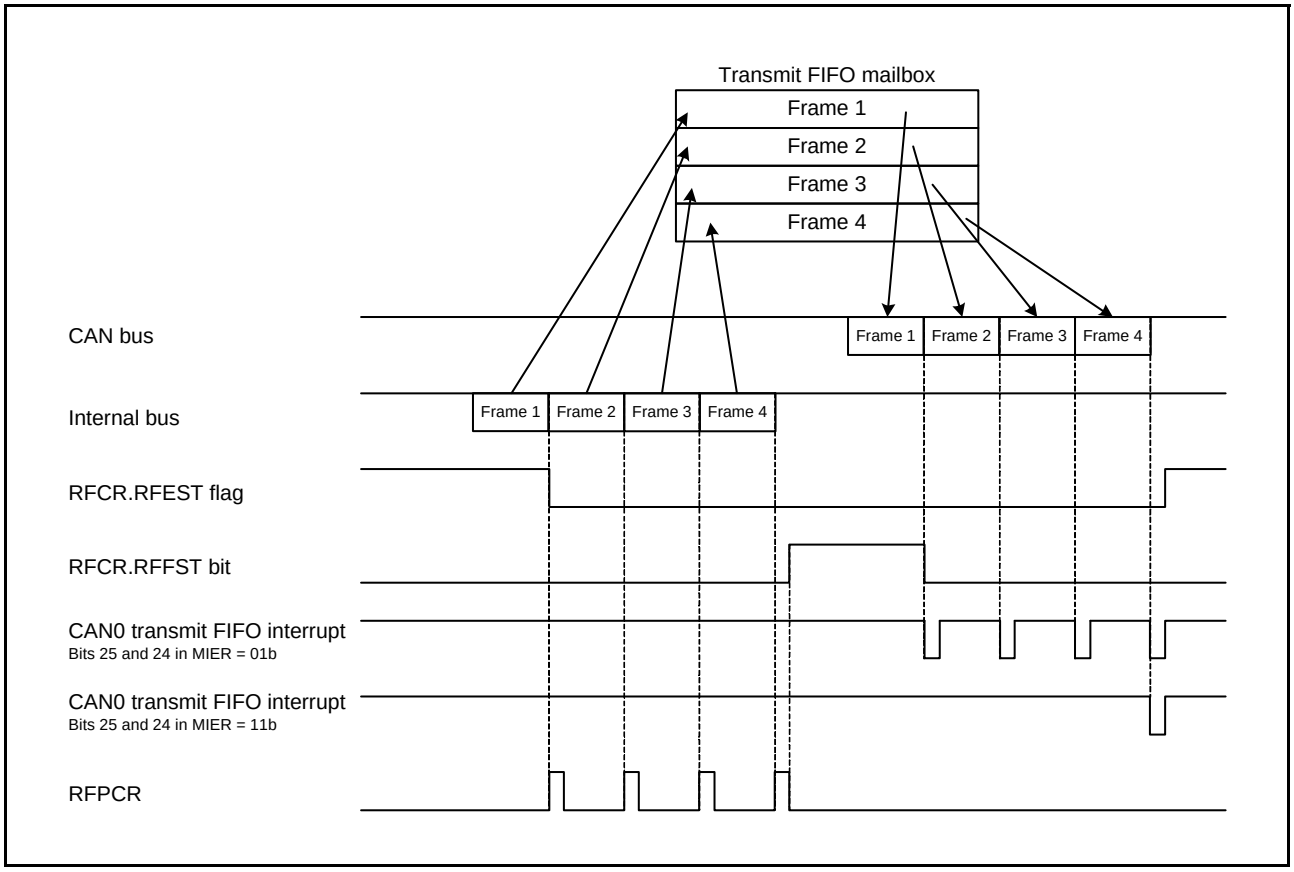


Figure 25.3 Transmit FIFO Mailbox Operation (Bits 25 and 24 in MIER = 01b or 11b)

25.2.12 Transmit FIFO Pointer Control Register (TFPCR)

Address: 0009 084Bh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—
Value after reset:	x	x	x	x	x	x	x	x

[Legend] x: Undefined

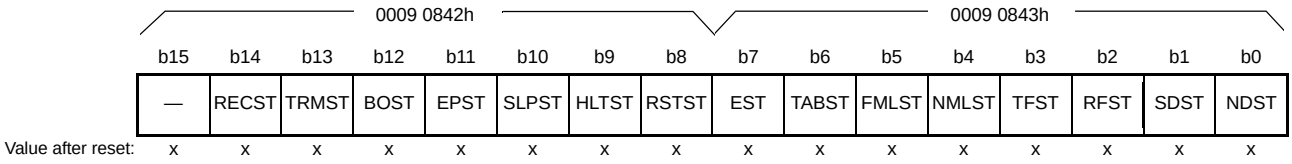
Bit	Symbol	Bit Name	Description	R/W
b7 to b0	—	—	The CPU-side pointer for the transmit FIFO is incremented by writing FFh to TFPCR.	W

When the transmit FIFO is not full, write FFh to TFPCR by a program to increment the CPU-side pointer for the transmit FIFO to the next mailbox location.

Do not write to TFPCR when the TFE bit in TFCR is 0 (transmit FIFO disabled).

25.2.13 Status Register (STR)

Address: 0009 0842h



[Legend] x: Undefined

Bit	Symbol	Bit Name	Description	R/W
b0	NDST	NEWDATA Status Flag	0: No mailbox with NEWDATA bit = 1 1: Mailbox(es) with NEWDATA bit = 1	R
b1	SDST	SENTDATA Status Flag	0: No mailbox with SENTDATA bit = 1 1: Mailbox(es) with SENTDATA bit = 1	R
b2	RFST	Receive FIFO Status Flag	0: No message in receive FIFO (empty) 1: Message in receive FIFO	R
b3	TFST	Transmit FIFO Status Flag	0: Transmit FIFO is full 1: Transmit FIFO is not full	R
b4	NMLST	Normal Mailbox Message Lost Status Flag	0: No mailbox with MSGLOST bit = 1 1: Mailbox(es) with MSGLOST bit = 1	R
b5	FMLST	FIFO Mailbox Message Lost Status Flag	0: RFMLF bit = 0 1: RFMLF bit = 1	R
b6	TABST	Transmission Abort Status Flag	0: No mailbox with TRMABT bit = 1 1: Mailbox(es) with TRMABT bit = 1	R
b7	EST	Error Status Flag	0: No error occurred 1: Error occurred	R
b8	RSTST	CAN Reset Status Flag	0: Not in CAN reset mode 1: In CAN reset mode	R
b9	HLTST	CAN Halt Status Flag	0: Not in CAN halt mode 1: In CAN halt mode	R
b10	SLPST	CAN Sleep Status Flag	0: Not in CAN sleep mode 1: In CAN sleep mode	R
b11	EPST	Error-Passive Status Flag	0: Not in error-passive state 1: In error-passive state	R
b12	BOST	Bus-Off Status Flag	0: Not in bus-off state 1: In bus-off state	R
b13	TRMST	Transmit Status Flag (transmitter)	0: Bus idle or reception in progress 1: Transmission in progress or in bus-off state	R
b14	RECST	Receive Status Flag (receiver)	0: Bus idle or transmission in progress 1: Reception in progress	R
b15	—	Reserved	The read value is undefined. The write value should always be 0.	R

NDST Flag (NEWDATA Status Flag)

The NDST flag is set to 1 when at least one NEWDATA flag in MCTLj (j = 0 to 31) is 1 regardless of the value of MIER. The NDST flag is set to 0 when all NEWDATA flags are 0.

SDST Flag (SENTDATA Status Flag)

The SDST flag is set to 1 when at least one SENTDATA flag in MCTLj (j = 0 to 31) is 1 regardless of the value of MIER. The SDST flag is set to 0 when all SENTDATA flags in MCTLj are 0.

RFST Flag (Receive FIFO Status Flag)

The RFST flag is set to 1 when the receive FIFO is not empty. The RFST flag is set to 0 when the receive FIFO is empty or normal mailbox mode is selected.

TFST Flag (Transmit FIFO Status Flag)

The TFST flag is set to 1 when the transmit FIFO is not full. The TFST flag is set to 0 when the transmit FIFO is full or normal mailbox mode is selected.

NMLST Flag (Normal Mailbox Message Lost Status Flag)

The NMLST flag is set to 1 when at least one MSGLOST flag inMCTLj (j = 0 to 31) is 1 regardless of the value of MIER. The NMLST flag is set to 0 when all MSGLOST flags in MCTLj are 0.

FMLST Flag (FIFO Mailbox Message Lost Status Flag)

The FMLST flag is set to 1 when the RFMLF flag in RFCR is 1 regardless of the value of MIER. The FMLST flag is set to 0 when the RFMLF flag in RFCR is 0.

TABST Flag (Transmission Abort Status Flag)

The TABST flag is set to 1 when at least one TRMABT flag in MCTLj (j = 0 to 31) is 1 regardless of the value of MIER.The TABST flag is set to 0 when all TRMABT flags in MCTLj are 0.

EST Flag (Error Status Flag)

The EST flag is set to 1 when at least one error is detected by EIFR regardless of the value of EIER. The EST flag is set to 0 when no error is detected by EIFR.

RSTST Flag (CAN Reset Status Flag)

The RSTST flag is set to 1 when the CAN module is in CAN reset mode. The RSTST flag is 0 when the CAN module is not in CAN reset mode or not in the state from CAN reset mode to CAN sleep mode. Even when the state is changed from CAN reset mode to CAN sleep mode, the RSTST flag remains 1.

HLTST Flag (CAN Halt Status Flag)

The HLTST flag is set to 1 when the CAN module is in CAN halt mode. The HLTST flag is 0 when the CAN module is not in CAN halt mode or not in the state from CAN halt mode to CAN sleep mode. Even when the state is changed from CAN halt mode to CAN sleep mode, the HLTST flag remains 1.

SLPST Flag (CAN Sleep Status Flag)

The SLPST flag is set to 1 when the CAN module is in CAN sleep mode. The SLPST flag is set to 0 when the CAN module is not in CAN sleep mode.

EPST Flag (Error-Passive Status Flag)

The EPST flag is set to 1 when the value of TECR or RECR exceeds 127 and the CAN module is in the error-passive state (128 ≤ TEC < 256 or 128 ≤ REC < 256). The EPST flag is set to 0 when the CAN module is not in the error-passive state.

BOST Flag (Bus-Off Status Flag)

The BOST flag is set to 1 when the value of TECR exceeds 255 and the CAN module is in the bus-off state (TEC ≥ 256). The BOST flag is set to 0 when the CAN module is not in the bus-off state.

TRMST Flag (Transmit Status Flag) (transmitter)

The TRMST flag is set to 1 when the CAN module performs as a transmitter node or is in the bus-off state. The TRMST flag is set to 0 when the CAN module performs as a receiver node or is in the bus-idle state.

RECST Flag (Receive Status Flag) (receiver)

The RECST flag is set to 1 when the CAN module performs as a receiver node. The RECST flag is set to 0 when the CAN module performs as a transmitter node or is in the bus-idle state.

25.2.14 Mailbox Search Mode Register (MSMR)

Address: 0009 0853h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	MBSM[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1 to b0	MBSM[1:0]	Mailbox Search Mode Select	00: Receive mailbox search mode 01: Transmit mailbox search mode 10: Message lost search mode 11: Channel search mode	R/W
b7 to b2	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

Write to MSMR in CAN operation mode or CAN halt mode.

MBSM[1:0] Bits (Mailbox Search Mode Select)

The MBSM[1:0] bits select the search mode for the mailbox search function.

When the MBSM[1:0] bits are 00b, receive mailbox search mode is selected. In this mode, the search targets are the NEWDATA flag in MCTLj (j = 0 to 31) for the normal mailbox and the RFEST flag in RFCR.

When the MBSM[1:0] bits are 01b, transmit mailbox search mode is selected. In this mode, the search target is the SENTDATA flag in MCTLj.

When the MBSM[1:0] bits are 10b, message lost search mode is selected. In this mode, the search targets are the MSGLOST flag in MCTLj for the normal mailbox and the RFMLF flag in RFCR.

When the MBSM[1:0] bits are 11b, channel search mode is selected. In this mode, the search target is CSSR. Refer to section 25.2.16, Channel Search Support Register (CSSR).

25.2.15 Mailbox Search Status Register (MSSR)

Address: 0009 0852h

	b7	b6	b5	b4	b3	b2	b1	b0
	SEST	—	—	MBNST[4:0]				
Value after reset:	1	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b4 to b0	MBNST[4:0]	Search Result Mailbox Number Status	These bits output the smallest mailbox number that is searched in each mode of MSMR.	R
b6, b5	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7	SEST	Search Result Status	0: Search result found 1: No search result	R

MBNST[4:0] Bits (Search Result Mailbox Number Status)

The MBNST[4:0] bits output the smallest mailbox number that is searched in each mode of MSMR. In receive mailbox search mode, transmit mailbox search mode, and message lost search mode, the value of the mailbox i.e., the search result to be output, is updated as described below:

- When the NEWDATA, SENTDATA or MSGLOST flag in MCTj (j = 0 to 31) for the output mailbox is set to 0
- When the NEWDATA, SENTDATA or MSGLOST flag in MCTj (j = 0 to 31) for a higher-priority mailbox is set to 1

If the MBSM[1:0] bits in MSMR are set to 00b (receive mailbox search mode) or 10b (message lost search mode), the receive FIFO (mailbox [28]) is output when the receive FIFO is not empty and there are no unread received messages or no lost messages in any of the normal mailboxes (mailboxes [0] to [23]). If the MBSM[1:0] bits in MSMR are set to 01b (transmit mailbox search mode), the transmit FIFO (mailbox [24]) is not output. Table 25.7 lists the behavior of the MBNST[4:0] bits in FIFO mailbox mode.

In channel search mode, the MBNST[4:0] bits output the corresponding channel number. After MSSR is read by a program, the next target channel number is output.

SEST Bit (Search Result Status)

The SEST bit is set to 1 (no search result) when no corresponding mailbox is found after searching all mailboxes. For example, in transmit mailbox search mode, the SEST bit is set to 1 when no SENTDATA flag in MCTj for mailboxes is 1. The SEST bit is set to 0 when at least one SENTDATA bit is 1. When the SEST bit is 1, the value of the MBNST[4:0] bits is undefined.

Table 25.7 Behavior of MBNST[4:0] Bits in FIFO Mailbox Mode

MSMR.MBSM [1:0] Bits	Mailbox [24] (Transmit FIFO)	Mailbox [28] (Receive FIFO)
00	Mailbox [24] is not output.	Mailbox [28] is output when no MCTLj.NEWDATA flag for the normal mailboxes is set to 1 (new message is being stored or has been stored to the mailbox) and the receive FIFO is not empty.(j = 0 to 23)
01		Mailbox [28] is not output.
10		Mailbox [28] is output when no MCTLj.MSGLOST flag for the normal mailboxes is set to 1 (message is overwritten or overrun) and the RFCR.RFMLF flag is set to 1 (receive FIFO message lost has occurred) in the receive FIFO.(j = 0 to 23)
11		Mailbox [28] is not output.

25.2.16 Channel Search Support Register (CSSR)

Address: 0009 0851h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—
Value after reset:	x	x	x	x	x	x	x	x

x: Undefined

Bit	Symbol	Bit Name	Description	R/W
b7 to b0	—	—	When the value for the channel search is input, the channel number is output to MSSR.	R/W

The bits in CSSR, which are set to 1, are encoded by an 8/3 encoder (the LSB position has the higher priority) and output to the MBNST[4:0] bits in MSSR.
MSSR outputs the updated value whenever MSSR is read by a program.
Write to CSSR only when the MBSM[1:0] bits in MSMR are 11 (channel search mode). Do not write to CSSR in CAN reset mode.

Figure 25.4 shows the write and read of CSSR and MSSR.

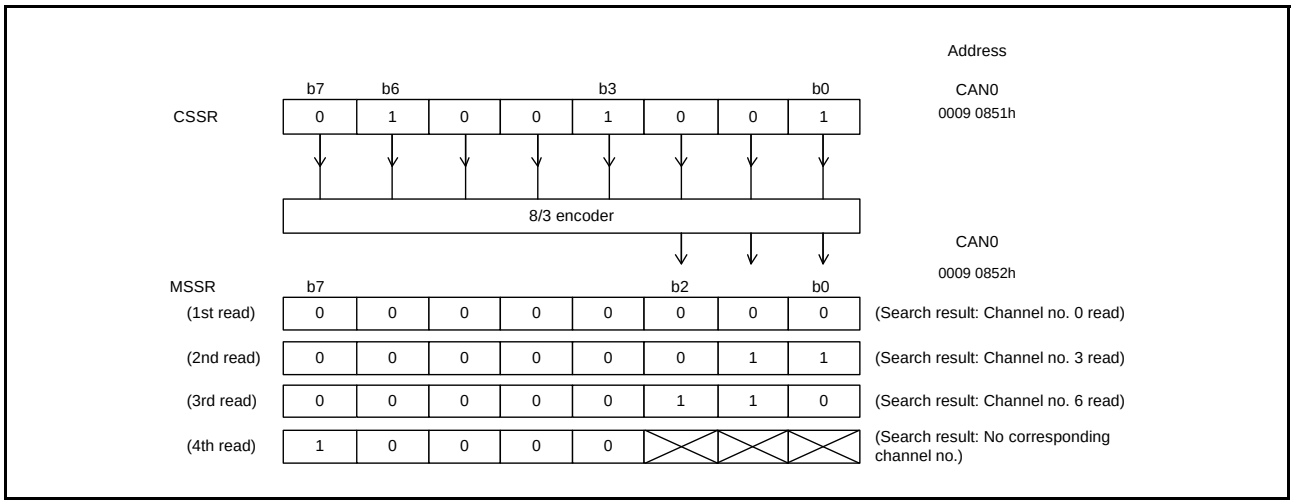


Figure 25.4 Write and Read of CSSR and MSSR

The value of CSSR is also updated whenever MSSR is read. When read, the value prior to conversion by the 8/3 encoder can be read.

25.2.17 Acceptance Filter Support Register (AFSR)

Address: 0009 0856h

	0009 0856h								0009 0857h							
	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Value after reset:	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

x: Undefined

Bit	Symbol	Bit Name	Description	R/W
b15 to b0	—	—	After the standard ID of a received message is written, the value converted for data table search can be read.	R/W

The acceptance filter support unit (ASU) can be used for data table (8 bits × 256) search. In the data table, all standard IDs created by the user are set to be valid/invalid in bit units. When AFSR is written with data in 16-bit units including the SID[10:0] bit in MBj (j = 0 to 31), in which a received standard ID is stored, a decoded row (byte offset) position and column (bit) position for data table search can be read. The ASU can be used for standard (11-bit) IDs only.
The ASU is enabled in the following cases:

- When the ID to receive cannot be masked by the acceptance filter
  (Example) IDs to receive: 078h, 087h, and 111h
- When there are too many IDs to receive and software filtering time is expected to be shortened

It should be noted that AFSR cannot be set in CAN reset mode.

Table 25.5 shows the write and read of AFSR.

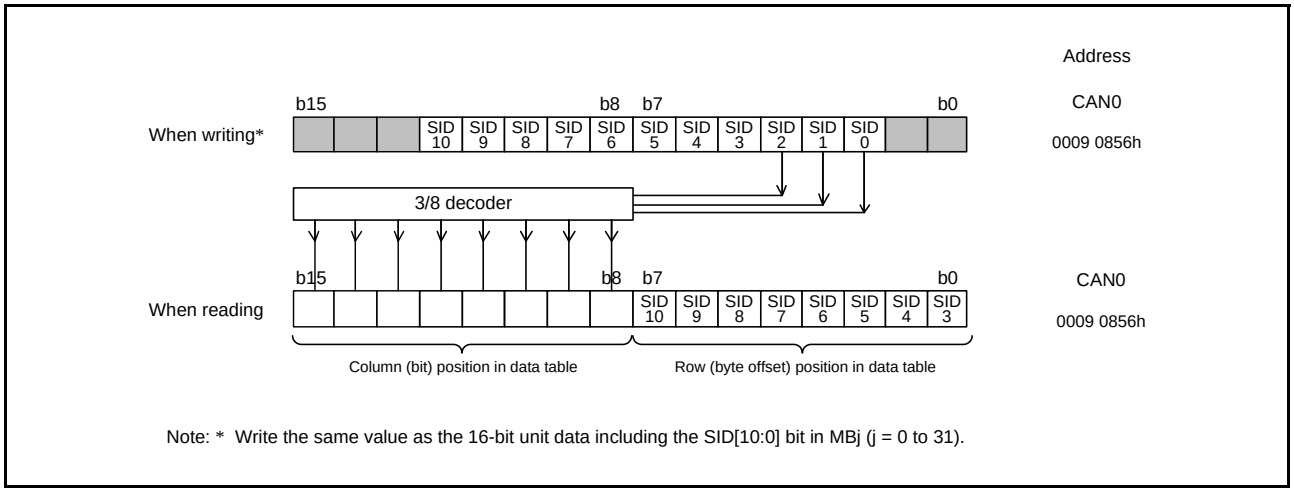


Figure 25.5 Write and Read of AFSR

25.2.18 Error Interrupt Enable Register (EIER)

Address: 0009 084Ch

	b7	b6	b5	b4	b3	b2	b1	b0
	BLIE	OLIE	ORIE	BORIE	BOEIE	EPIE	EWIE	BEIE
Value after reset:	1	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	BEIE	Bus Error Interrupt Enable	0: Bus error interrupt disabled 1: Bus error interrupt enabled	R/W
b1	EWIE	Error-Warning Interrupt Enable	0: Error-warning interrupt disabled 1: Error-warning interrupt enabled	R/W
b2	EPIE	Error-Passive Interrupt Enable	0: Error-passive interrupt disabled 1: Error-passive interrupt enabled	R/W
b3	BOEIE	Bus-Off Entry Interrupt Enable	0: Bus-off entry interrupt disabled 1: Bus-off entry interrupt enabled	R/W
b4	BORIE	Bus-Off Recovery Interrupt Enable	0: Bus-off recovery interrupt disabled 1: Bus-off recovery interrupt enabled	R/W
b5	ORIE	Overrun Interrupt Enable	0: Receive overrun interrupt disabled 1: Receive overrun interrupt enabled	R/W
b6	OLIE	Overload Frame Transmit Interrupt Enable	0: Overload frame transmit interrupt disabled 1: Overload frame transmit interrupt enabled	R/W
b7	BLIE	Bus Lock Interrupt Enable	0: Bus lock interrupt disabled 1: Bus lock interrupt enabled	R/W

EIER is used to enable or disable the error interrupt individually for each error interrupt source in EIFR.
Write to EIER in CAN reset mode.

BEIE Bit (Bus Error Interrupt Enable)

When the BEIE bit is 0, no error interrupt request is generated even if the BEIF flag in EIFR is set to 1. When the BEIE bit is 1, an error interrupt request is generated if the BEIF flag in EIFR is set to 1.

EWIE Bit (Error-Warning Interrupt Enable)

When the EWIE bit is 0, no error interrupt request is generated even if the EWIF flag in EIFR is set to 1. When the EWIE bit is 1, an error interrupt request is generated if the EWIF flag in EIFR is set to 1.

EPIE Bit (Error-Passive Interrupt Enable)

When the EPIE bit is 0, no error interrupt request is generated even if the EPIF flag in EIFR is set to 1. When the EPIE bit is 1, an error interrupt request is generated if the EPIF flag in EIFR is set to 1.

BOEIE Bit (Bus-Off Entry Interrupt Enable)

When the BOEIE bit is 0, no error interrupt request is generated even if the BOEIF flag in EIFR is set to 1. When the BOEIE bit is 1, an error interrupt request is generated if the BOEIF flag in EIFR is set to 1.

BORIE Bit (Bus-Off Recovery Interrupt Enable)

When the BORIE bit is 0, an error interrupt request is not generated even if the BORIF flag in EIFR is set to 1. When the BORIE bit is set to 1, an error interrupt request is generated if the BORIF flag in EIFR t is set to 1.

ORIE Bit (Overrun Interrupt Enable)

When the ORIE bit is 0, an error interrupt request is not generated even if the ORIF flag in EIFR is set to 1. When the ORIE bit is 1, an error interrupt request is generated if the ORIF flag in EIFR is set to 1.

OLIE Bit (Overload Frame Transmit Interrupt Enable)

When the OLIE bit is 0, no error interrupt request is generated even if the OLIF flag in EIFR is set to 1. When the OLIE bit is 1, an error interrupt request is generated if the OLIF flag in EIFR is set to 1.

BLIE Bit (Bus Lock Interrupt Enable)

When the BLIE bit is 0, no error interrupt request is generated even if the BLIF flag in EIFR is set to 1. When the BLIE bit is 1, an error interrupt request is generated if the BLIF flag in EIFR is set to 1.

25.2.19 Error Interrupt Factor Judge Register (EIFR)

Address: 0009 084Dh

	b7	b6	b5	b4	b3	b2	b1	b0
	BLIF	OLIF	ORIF	BORIF	BOEIF	EPIF	EWIF	BEIF
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	BEIF	Bus Error Detect Flag	0: No bus error detected 1: Bus error detected	R/W
b1	EWIF	Error-Warning Detect Flag	0: No error-warning detected 1: Error-warning detected	R/W
b2	EPIF	Error-Passive Detect Flag	0: No error-passive detected 1: Error-passive detected	R/W
b3	BOEIF	Bus-Off Entry Detect Flag	0: No bus-off entry detected 1: Bus-off entry detected	R/W
b4	BORIF	Bus-Off Recovery Detect Flag	0: No bus-off recovery detected 1: Bus-off recovery detected	R/W
b5	ORIF	Receive Overrun Detect Flag	0: No receive overrun detected 1: Receive overrun detected	R/W
b6	OLIF	Overload Frame Transmission Detect Flag	0: No overload frame transmission detected 1: Overload frame transmission detected	R/W
b7	BLIF	Bus Lock Detect Flag	0: No bus lock detected 1: Bus lock detected	R/W

If an event corresponding to each flag occurs, the corresponding flag in EIFR is set to 1 regardless of the setting of EIER. To set each flag to 0, write 0 by a program. If the set timing occurs simultaneously with the clear timing by the program, the flag becomes 1.

When a single flag is set to 0 by a program, do not use the logic operation instruction (AND.B) – use the transfer instruction (MOV) to ensure that only the specified flag is set to 0 and the other flags are set to 1. Writing 1 has no effect to these bit values.

BEIF Flag (Bus Error Detect Flag)

The BEIF flag is set to 1 when a bus error is detected.

EWIF Flag (Error-Warning Detect Flag)

The EWIF flag is set to 1 when the value of the receive error counter (REC) or transmit error counter (TEC) exceeds 95. The EWIF flag is set to 1 only when the REC or TEC initially exceeds 95. Thus, if 0 is written to the EWIF flag by a program while the REC or TEC remains greater than 95, the EWIF flag is not set to 1 until the REC or TEC goes below 95 and then exceeds 95 again.

EPIF Flag (Error-Passive Detect Flag)

The EPIF flag is set to 1 when the CAN error state becomes error-passive (the REC (receive error counter) or TEC (transmit error counter) value exceeds 127).
The EPIF flag is set to 1 only when the REC or TEC initially exceeds 127. Thus, if 0 is written by a program while the REC or TEC remains greater than 127, the EPIF flag is not set to 1 until the REC or TEC goes below 127 and then exceeds 127 again.

BOEIF Flag (Bus-Off Entry Detect Flag)

The BOEIF bit is set to 1 when the CAN error state becomes bus-off (the TEC (transmit error counter) value exceeds 255). The BOEIF bit is also set to 1 when the BOM[1:0] bits in CTLR are 01 (entry to CAN halt mode automatically at bus-off entry) and the CAN module becomes the bus-off state.

BORIF Flag (Bus-Off Recovery Detect Flag)

The BORIF bit is set to 1 when the CAN module recovers from the bus-off state normally by detecting 11 consecutive bits 128 times in the following conditions:

- When the BOM[1:0] bits in CTLR are 00b
- When the BOM[1:0] bits in CTLR are 10b
- When the BOM[1:0] bits in CTLR are 11b

However, the BORIF bit is not set to 1 if the CAN module recovers from the bus-off state in the following conditions:

- When the CANM[1:0] bits in CTLR are set to 01b or 11b (CAN reset mode)
- When the RBOC bit in CTLR is set to 1 (forcible return from bus-off)
- When the BOM[1:0] bits in CTLR are set to 01b
- When the BOM[1:0] bits in CTLR are set to 11b and the CANM[1:0] bits in CTLR are set to 10b (CAN halt mode) before normal recovery occurs

ORIF Flag (Receive Overrun Detect Flag)

The ORIF bit is set to 1 when a receive overrun occurs. This bit is not to set to 1 in overwrite mode.
In overwrite mode, a reception complete interrupt request is generated if an overwrite condition occurs and the ORIF bit is not set to 1.
In normal mailbox mode, if an overrun occurs in any of mailboxes [0] to [31] in overrun mode, this bit is set to 1. In FIFO mailbox mode, if an overrun occurs in any of mailboxes [0] to [23] or the receive FIFO in overrun mode, this bit is set to 1.

OLIF Flag (Overload Frame Transmission Detect Flag)

The OLIF bit is set to 1 if the transmitting condition of an overload frame is detected when the CAN module performs transmission or reception.

BLIF Flag (Bus Lock Detect Flag)

The BLIF bit is set to 1 if 32 consecutive dominant bits are detected on the CAN bus while the CAN module is in CAN operation mode.

After the BLIF bit is set to 1, 32 consecutive dominant bits are detected again under either of the following conditions:

- After this bit is set to 0 from 1, recessive bits are detected
- After this bit is set to 0 from 1, the CAN module enters CAN reset mode or CAN halt mode and then enters CAN operation mode again.

Table 25.8 lists the behavior of flags BOEIF and BORIF according to the CTLR.BOM[1:0] bit setting.

Table 25.8 Behavior of BOEIF and BORIF Flags according to CTLR.BOM[1:0] Bit Setting

CTLR.BOM[1:0] Bits	BOEIF Flag	BORIF Flag
00	Set to 1 on entry to the bus-off state.	Set to 1 on exit from the bus-off state.
01		Do not set to 1.
10		Set to 1 on exit from the bus-off state.
11		Set to 1 if normal bus-off recovery occurs before the CTLR.CANM[1:0] bits are set to 10 (CAN halt mode).

25.2.20 CAN0 Receive Error Count Register (RECR)

Address: 0009 084Eh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b7 to b0	—	Receive Error Count Function	RECR increments or decrements the counter value according to the error status of the CAN module during reception.	R

RECR indicates the value of the receive error counter.

Refer to the CAN Specifications (ISO11898-1) about the increment/decrement conditions of the receive error counter.

The value of RECR in the bus-off state is undefined.

25.2.21 Transmit Error Count Register (TECR)

Address: 0009 084Fh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b7 to b0	—	Transmit Error Count Function	TECR increments or decrements the counter value according to the error status of the CAN module during transmission.	R

TECR indicates the value of the transmit error counter.
Refer to the CAN Specifications (ISO11898-1) about the increment/decrement conditions of the transmit error counter.
The value of TECR in the bus-off state is undefined.

25.2.22 Error Code Store Register (ECSR)

Address: 0009 0850h

	b7	b6	b5	b4	b3	b2	b1	b0
	EDPM	ADEF	BE0F	BE1F	CEF	AEF	FEF	SEF
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	SEF	Stuff Error Flag*3*4	0: No stuff error detected 1: Stuff error detected	R/W
b1	FEF	Form Error Flag*3*4	0: No form error detected 1: Form error detected	R/W
b2	AEF	ACK Error Flag*3*4	0: No ACK error detected 1: ACK error detected	R/W
b3	CEF	CRC Error Flag*3*4	0: No CRC error detected 1: CRC error detected	R/W
b4	BE1F	Bit Error (recessive) Flag*3*4	0: No bit error (recessive) detected 1: Bit error (recessive) detected	R/W
b5	BE0F	Bit Error (dominant) Flag*3*4	0: No bit error (dominant) detected 1: Bit error (dominant) detected	R/W
b6	ADEF	ACK Delimiter Error Flag*3*4	0: No ACK delimiter error detected 1: ACK delimiter error detected	R/W
b7	EDPM	Error Display Mode Select*1*2	0: Output of first detected error code 1: Output of accumulated error code	R/W

Note 1. Write to the EDPM bit in CAN reset mode or CAN halt mode.
Note 2. If more than one error condition is detected simultaneously, all related bits are set to 1.
Note 3. Writing 1 has no effect to these bit values.
Note 4. To write 0 to flags SEF, FEF, AEF, CEF, BE1F, BE0F, and ADEF, do not use the logic operation instruction (AND.B). Use the transfer (MOV) instruction to ensure that only the specified flag is set to 0 and the other flags are set to 1.

ECSR can be used to monitor whether an error has occurred on the CAN bus.
Refer to the CAN Specifications (ISO11898-1) to check the generation conditions of each error.
To set each bit except for the EDPM flag to 0, write 0 by a program. If the timing at which each flag is set to 1 and the timing at which 0 is written by a program are the same, the relevant flag is set to 1.

SEF Flag (Stuff Error Flag)

The SEF bit is set to 1 when a stuff error is detected.

FEF Flag (Form Error Flag)

The FEF bit is set to 1 when a form error is detected.

AEF Flag (ACK Error Flag)

The AEF bit is set to 1 when an ACK error is detected.

CEF Flag (CRC Error Flag)

The CEF bit is set to 1 when a CRC error is detected.

BE1F Flag (Bit Error (recessive) Flag)

The BE1F bit is set to 1 when a recessive bit error is detected.

BE0F Flag (Bit Error (dominant) Flag)

The BE0F bit is set to 1 when a dominant bit error is detected.

ADEF Flag (ACK Delimiter Error Flag)

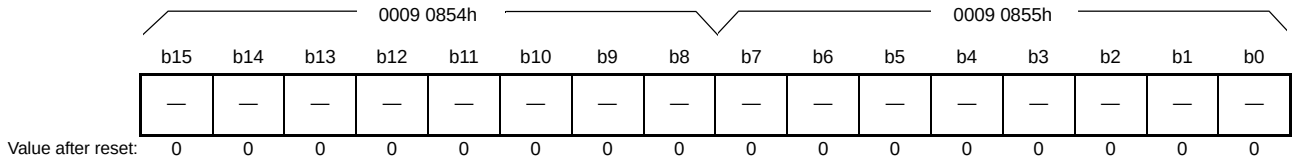
The ADEF bit is set to 1 when a form error is detected with the ACK delimiter during transmission.

EDPM Bit (Error Display Mode Select)

The EDPM bit selects the output mode of ECSR. When the EDPM bit is set to 0, ECSR outputs the first error code. When the EDPM bit is set to 1, ECSR outputs the accumulated error code.

25.2.23 Time Stamp Register (TSR)

Address: 0009 0854h



Bit	Symbol	Bit Name	Description	R/W
b15 to b0	—	Time Stamp Register	Free-running counter value for the time stamp function	R

Note 1. Read TSR in 16-bit units.

When TSR is read, the value of the time stamp counter (16-bit free-running counter) at that moment is read.
The value of the time stamp counter reference clock is a multiple of 1 bit time, as configured by the TSPS[1:0] bits in CTLR.
The time stamp counter stops in CAN sleep mode and CAN halt mode, and is initialized in CAN reset mode.
The time stamp counter value is stored to bits TSL[7:0] and TSH[7:0] in MBj when a received message is stored in a receive mailbox.

25.2.24 Test Control Register (TCR)

Address: 0009 0858h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	TSTM[1:0]		TSTE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	TSTE	CAN Test Mode Enable	0: CAN test mode disabled 1: CAN test mode enabled	R/W
b2, b1	TSTM[1:0]	CAN Test Mode Select	b2 b1 0 0: Other than CAN test mode 0 1: Listen-only mode 1 0: Self-test mode 0 (external loopback) 1 1: Self-test mode 1 (internal loopback)	R/W
b7 to b3	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

TCR controls the CAN test mode. Write to TCR in CAN halt mode only.

(1) Listen-Only Mode

The CAN Specifications (ISO11898-1) recommend an optional bus monitoring mode. In listen-only mode, valid data frames and valid remote frames can be received. However, only recessive bits can be sent on the CAN bus, and the ACK bit, overload flag, and active error flag cannot be sent.

Listen-only mode can be used for baud rate detection.

Do not request transmission from any mailboxes in listen-only mode.

Figure 25.6 shows the connection when listen-only mode is selected.

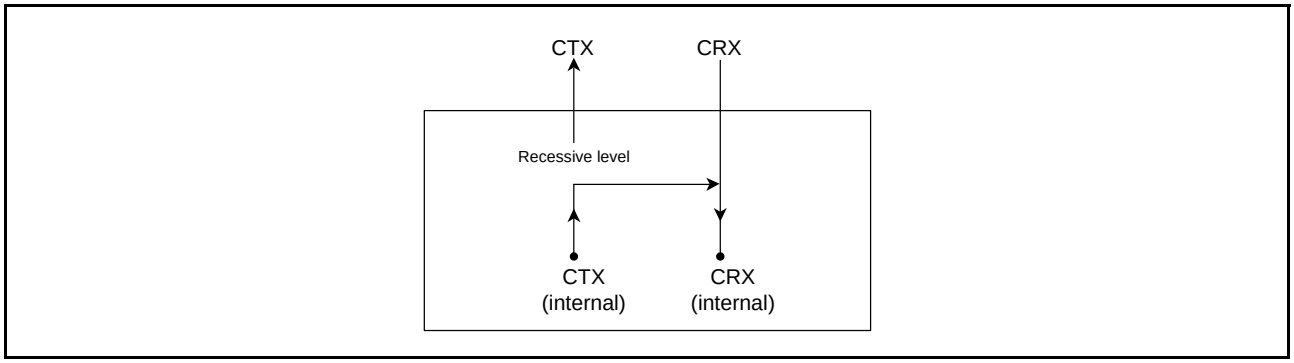


Figure 25.6 Connection when Listen-Only Mode is Selected

(2) Self-Test Mode 0 (External Loopback))

Self-test mode 0 is for testing the CAN transceiver (self-diagnostic function under a self-loaded condition). Connect the CTX and CRX pins to the CAN transceiver when this mode is to be used.
As a node, this module is capable of transmitting its own ACK bits in self-test mode 0, making self-diagnostic tests to check for normal CAN operation possible even when no other node is connected to the network.
Figure 25.7 shows the connection when self-test mode 0 is selected.

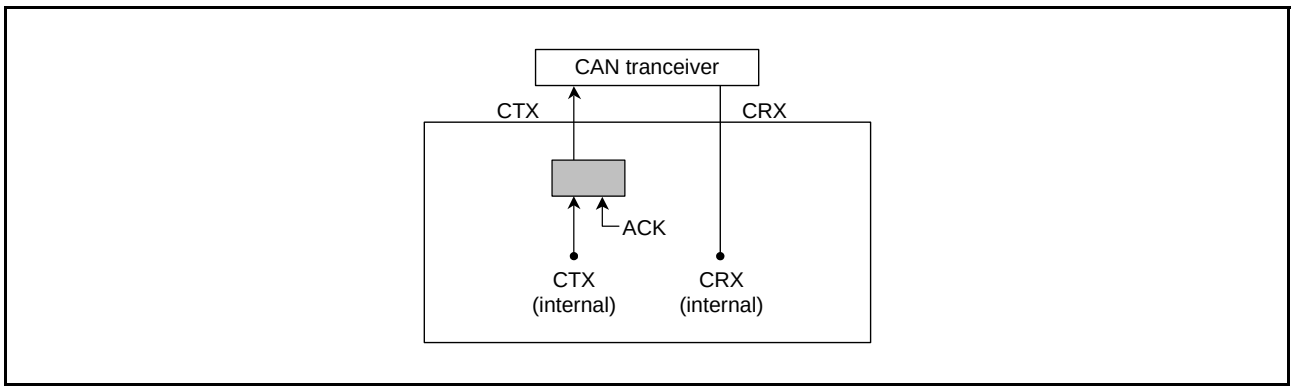


Figure 25.7 Connection when Self-Test Mode 0 is Selected

(3) Self-Test Mode 1 (Internal Loopback)

Self-test mode 1 is provided for self-test functions.
In self-test mode 1, the protocol controller treats its transmitted messages as received messages and stores them into the receive mailbox. To be independent from external stimulation, the protocol controller generates the ACK bit.
In self-test mode 1, the protocol controller performs an internal feedback from the internal CTX pin to the internal CRX pin. The input value of the external CRX pin is ignored. The external CTX pin outputs only recessive bits. The CTX and CRX pins do not need to be connected to the CAN bus or any external device.
Figure 25.8 shows the connection when self-test mode 1 is selected.

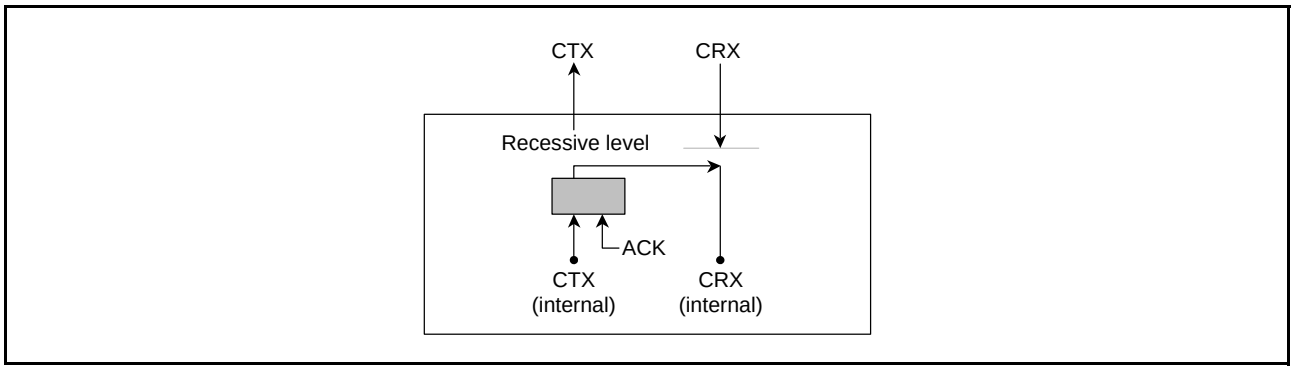


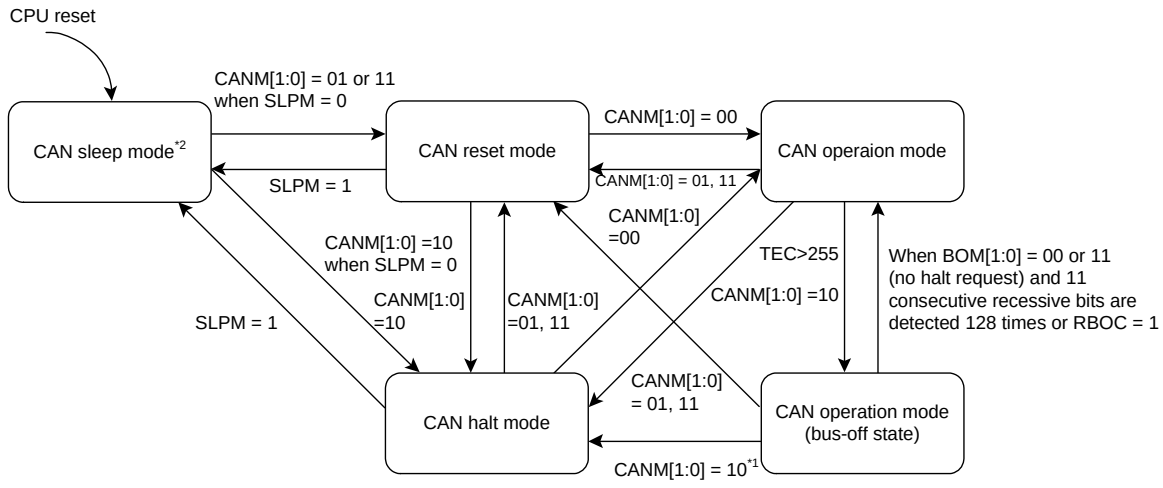
Figure 25.8 Connection when Self-Test Mode 1 is Selected

25.3 Operating Mode

The CAN module has the following four operating modes.

- CAN reset mode
- CAN halt mode
- CAN operation mode
- CAN sleep mode

Figure 25.9 shows the transition between CAN operating modes.



CANM, SLPM, BOM, RBOC: Bits in CTLR

Notes: 1. The transition timing from the bus-off state to CAN halt mode depends on the setting of the CTLR.BOM[1:0] bits.
— When the CTLR.BOM[1:0] bits are 01, the state transition timing is immediately after entering the bus-off state.
— When the CTLR.BOM[1:0] bits are 10, the state transition timing is at the end of the bus-off state.
— When the CTLR.BOM[1:0] bits are 11, the state transition timing is at the setting of the CTLR.CANM[1:0] bits to 10 (CAN halt mode).
2. Write 0 to only the CTLR.SLPM bit to exit CAN sleep mode. Only when the CAN module enters CAN sleep mode from CAN halt mode, the transition from CAN sleep mode to CAN halt mode is enabled

Figure 25.9 Transition between CAN Operating Modes

25.3.1 CAN Reset Mode

CAN reset mode is provided for CAN communication configuration.
When the CTLR.CANM[1:0] bits are set to 01 or 11, the CAN module enters CAN reset mode. Then, the STR.RSTST bit is set to 1. Do not change the CTLR.CANM[1:0] bits until the RSTST bit is set to 1. Set BCR before exiting CAN reset mode to any other modes.
The following registers are initialized to their reset values after entering CAN reset mode, and their initial values are retained during CAN reset mode:

- MCTLj (j = 0 to 31)
- STR (except for the SLPST and TFST bits)
- EIFR
- RECR
- TECR
- TSR
- MSSR
- MSMR
- RFCR
- TFCR
- TCR
- ECSR (except for the EDPM bit)

The following registers retain their previous values even after entering CAN reset mode.

- CTLR
- STR (only the SLPST and TFST bits)
- MIER
- EIER
- BCR
- CSSR
- ECSR (only the EDPM bit)
- MBj (j = 0 to 31)
- MKRi (i = 0 to 7)
- FIDCR0 and FIDCR1
- MKIVLR
- AFSR
- RFPCR
- TFPCR

25.3.2 CAN Halt Mode

CAN halt mode is used for mailbox configuration and test mode setting.
When the CTLR.CANM[1:0] bits are set to 10, CAN halt mode is selected. Then the STR.HLTST flag is set to 1. Do not change the CTLR.CANM[1:0] bits until the HLTST flag is set to 1.
See Table 25.9 for the state transition conditions when transmitting or receiving.
All registers except for flags RSTST, HLTST, and SLPST in STR remain unchanged when the CAN enters CAN halt mode.
Do not change CTLR (except for bits CANM[1:0] and SLPM), and EIER in CAN halt mode. BCR can be changed in CAN halt mode only when listen-only mode is selected for automatic baud rate detection.

Table 25.9 Operation in CAN Reset Mode and CAN Halt Mode

Mode	Receiver	Transmitter	Bus-Off
CAN reset mode (forcible transition) CANM[1:0] = 11	CAN module enters CAN reset mode without waiting for the end of message reception.	CAN module enters CAN reset mode without waiting for the end of message transmission.	CAN module enters CAN reset mode without waiting for the end of bus-off recovery.
CAN reset mode CANM[1:0] = 01	CAN module enters CAN reset mode without waiting for the end of message reception.	CAN module enters CAN reset mode after waiting for the end of message transmission.*1*4	CAN module enters CAN reset mode without waiting for the end of bus-off recovery.
CAN halt mode	CAN module enters CAN halt mode after waiting for the end of message reception.*2*3	CAN module enters CAN halt mode after waiting for the end of message transmission.*1*4	[When the CTLR.BOM[1:0] bits are 00] A halt request from a program will be accepted only after bus-off recovery. [When the CTLR.BOM[1:0] bits are 01] CAN module automatically enters CAN halt mode without waiting for the end of bus-off recovery (regardless of a halt request from a program). [When the CTLR.BOM[1:0] bits are 10] CAN module automatically enters CAN halt mode after waiting for the end of bus-off recovery (regardless of a halt request from a program). [When the CTLR.BOM[1:0] bits are 11] CAN module enters CAN halt mode (without waiting for the end of bus-off recovery) if a halt is requested by a program during bus-off.

Note 1. If several messages are requested to be transmitted, mode transition occurs after the completion of the first transmission. In a case that the CAN reset mode is being requested during suspend transmission, mode transition occurs when the bus is idle, the next transmission ends, or the CAN module becomes a receiver.
Note 2. If the CAN bus is locked at the dominant level, the program can detect this state by monitoring the BLIF flag in EIFR.
Note 3. If a CAN bus error occurs during reception after CAN halt mode is requested, the CAN module transits to CAN halt mode immediately.
Note 4. If a CAN bus error or arbitration lost occurs during transmission after CAN reset mode or CAN halt mode is requested, the CAN module transits to the requested CAN mode immediately.

25.3.3 CAN Sleep Mode

CAN sleep mode is used for reducing current consumption by stopping the clock supply to the CAN module. After an MCU pin reset or software reset, the CAN module starts from CAN sleep mode.
When the SLPM bit in CTLR is set to 1, the CAN module enters CAN sleep mode. Then, the SLPST flag in STR is set to 1. Do not change the value of the SLPM bit in CTLR until the SLPST flag in STR is set to 1. The other registers remain unchanged when the CAN module enters CAN sleep mode.
Write to the SLPM bit in CTLR in CAN reset mode and CAN halt mode. Do not change any registers (except for the SLPM bit in CTLR) during CAN sleep mode. Read operation is still allowed.
When the SLPM bit in CTLR is set to 0, the CAN module is released from CAN sleep mode. When the CAN module exits CAN sleep mode, the other registers remain unchanged.

25.3.4 CAN Operation Mode (Excluding Bus-Off State)

CAN operation mode is used for CAN communication.
When the CANM[1:0] bits in CTLR are set to 00, the CAN module enters CAN operation mode.
Then flags RSTST and HLTST in STR are set to 0. Do not change the value of the CANM[1:0] bits in CTLR until flags RSTST and HLTST in STR are set to 0.
If 11 consecutive recessive bits are detected after entering CAN operation mode, the CAN module is in the following states:

- The CAN module becomes an active node on the network, thus enabling transmission and reception of CAN messages.
- Error monitoring of the CAN bus, such as receive and transmit error counters, is performed.

During CAN operation mode, the CAN module may be in one of the following three sub-modes, depending on the status of the CAN bus.

- Idle mode: Transmission or reception is not being performed.
- Receive mode: A CAN message sent by another node is being received.
- Transmit mode:A CAN message is being transmitted. The CAN module may receive its own message simultaneously when self-test mode 0 (TSTM bits in TCR = 10) or self-test mode 1 (TSTM bits in TCR = 11) is selected.

Figure 25.10 shows the sub-modes of CAN operation mode.

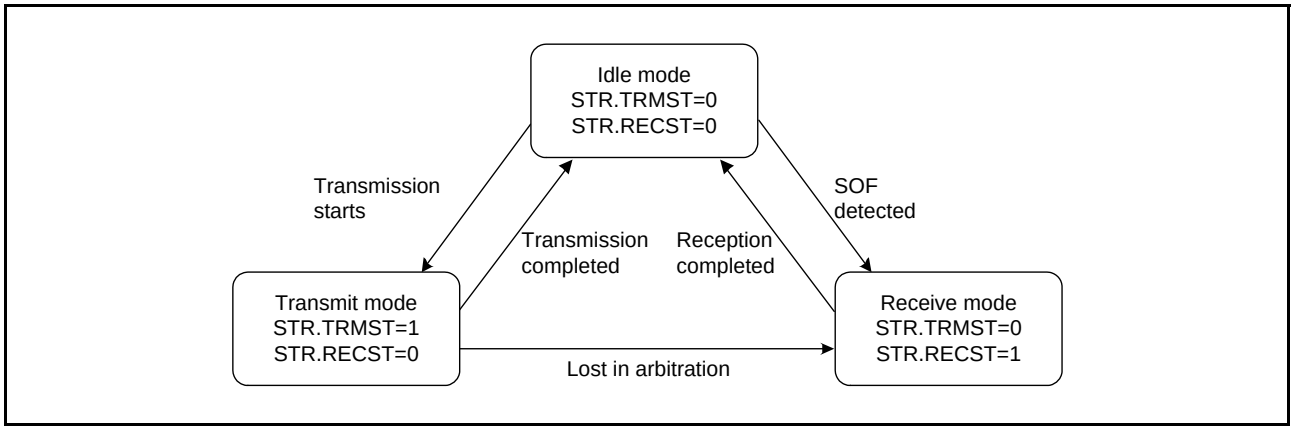


Figure 25.10 Sub-Modes of CAN Operation Mode

25.3.5 CAN Operation Mode (Bus-Off State)

The CAN module enters the bus-off state according to the increment/decrement rules for the transmit/error counters in the CAN Specifications.
The following cases apply when the CAN module is recovering from the bus-off state. When the CAN module is in the bus-off state, the values of the CAN-related registers, except for STR, EIFR, RECR, TECR and TSR, remain unchanged.

(1) When bits BOM[1:0] in CTLR are 00 (normal mode)

The CAN module enters the error-active state immediately after it has completed the recovery from the bus-off state and CAN communication is enabled instantly. The BORIF flag in EIFR is set to 1 (bus-off recovery detected) at this time.

(2) When bit RBOC in CTLR is set to 1 (forcible return from bus-off)

The CAN module enters the error-active state immediately when it is in the bus-off state and the RBOC bit in CTLR is set to 1. CAN communication is enabled again after 11 consecutive recessive bits are detected. The BORIF flag in EIFR is not set to 1 at this time.

(3) When bits BOM[1:0] in CTLR are 01 (automatic transition to CAN halt mode at bus-off entry)

The CAN module enters CAN halt mode immediately when it reaches the bus-off state. The BORIF flag in EIFR is not set to 1 at this time.

(4) When bits BOM[1:0] in CTLR are 10 (automatic transition to CAN halt mode at bus-off end)

The CAN module enters CAN halt mode when it has completed the recovery from bus-off. The BORIF flag in EIFR is set to 1 at this time.

(5) When bits BOM[1:0] in CTLR are 11 (transition to CAN halt mode by a program) and bits CANM[1:0] in CTLR are set to 10 (CAN halt mode) during bus-off state

The CAN module enters CAN halt mode immediately when it is in the bus-off state and the CANM[1:0] bits in CTLR are set to 10 (CAN halt mode). The BORIF flag in EIFR is not set to 1 at this time.
If the CANM[1:0] bits in CTLR are not set to 10 during bus-off, the same behavior as (1) applies.

25.4 CAN Communication Speed Setting

The following description explains about CAN communication speed setting.

25.4.1 CAN Clock Setting

This LSI has a CAN clock selector.
The CAN clock can be set by the BRP[9:0] bits in BCR.
Figure 25.11 shows a block diagram of the CAN clock generator.

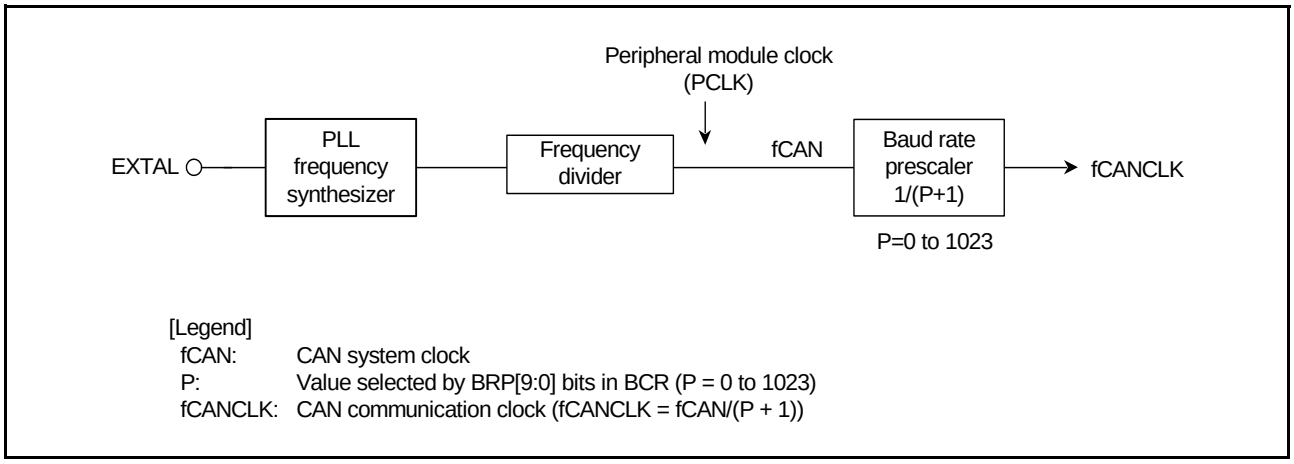


Figure 25.11 Block Diagram of CAN Clock Generator

25.4.2 Bit Timing Setting

The bit time consists of the following three segments.
Figure 25.12 shows the bit timing.

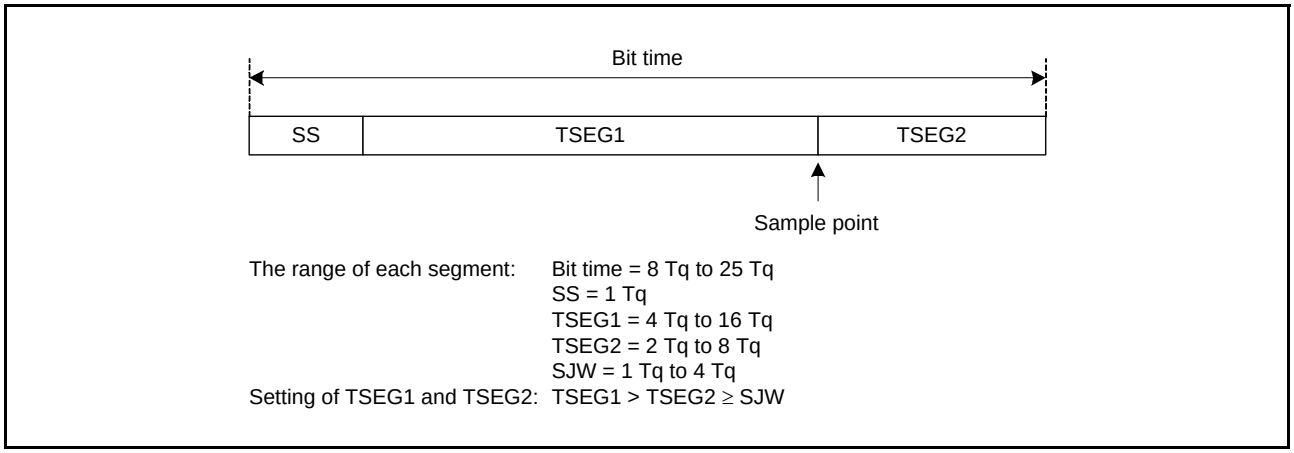


Figure 25.12 Bit Timing

25.4.3 Bit Rate

The bit rate depends on the division value of fCAN (CAN system clock), the division value of the baud rate prescaler, and the number of Tq of one bit time.

$$\text{Bit rate [bps]} = \frac{\text{fCAN}}{\text{Baud rate prescaler division value*1 x number of Tq of one bit time}} = \frac{\text{fCANCLK}}{\text{Number of Tq of one bit time}}$$

Note 1. Division value of baud rate prescaler = P + 1 (P: 0 to 1023)
Setting of the BRP[9:0] bits in BCR

Table 25.10 lists bit rate examples.

Table 25.10 Bit Rate Examples

fCAN	50 MHz		48 MHz		40 MHz		32 MHz	
Bit Rate	**Number of Tq**	**P + 1**	**Number of Tq**	**P + 1**	**Number of Tq**	**P + 1**	**Number of Tq**	**P + 1**
1 Mbps	10 Tq 25 Tq	5 2	8 Tq 12 Tq 16 Tq	6 4 3	10 Tq 20 Tq	4 2	8 Tq 16 Tq	4 2
500 kbps	10 Tq 25 Tq	10 4	8 Tq 12 Tq 16 Tq	12 8 6	10 Tq 20 Tq	8 4	8 Tq 16 Tq	8 4
250 kbps	10 Tq 25 Tq	20 8	8 Tq 12 Tq 16 Tq	24 16 12	10 Tq 20 Tq	16 8	8 Tq 16 Tq	16 8
125 kbps	10 Tq 25 Tq	40 16	8 Tq 12 Tq 16 Tq	48 32 24	10 Tq 20 Tq	32 16	8 Tq 16 Tq	32 16
83.3 kbps	10 Tq 25 Tq	60 24	8 Tq 12 Tq 16 Tq	72 48 36	8 Tq 10 Tq 16 Tq 20 Tq	60 48 30 24	8 Tq 16 Tq	48 24
33.3 kbps	10 Tq 25 Tq	150 60	8 Tq 12 Tq 16 Tq	180 120 90	8 Tq 10 Tq 20 Tq	150 120 60	8 Tq 10 Tq 16 Tq 20 Tq	120 96 60 48

25.5 Mailbox and Mask Register Structure

Figure 25.13 shows the structure of MBj.
There are 32 mailboxes with the same structure.

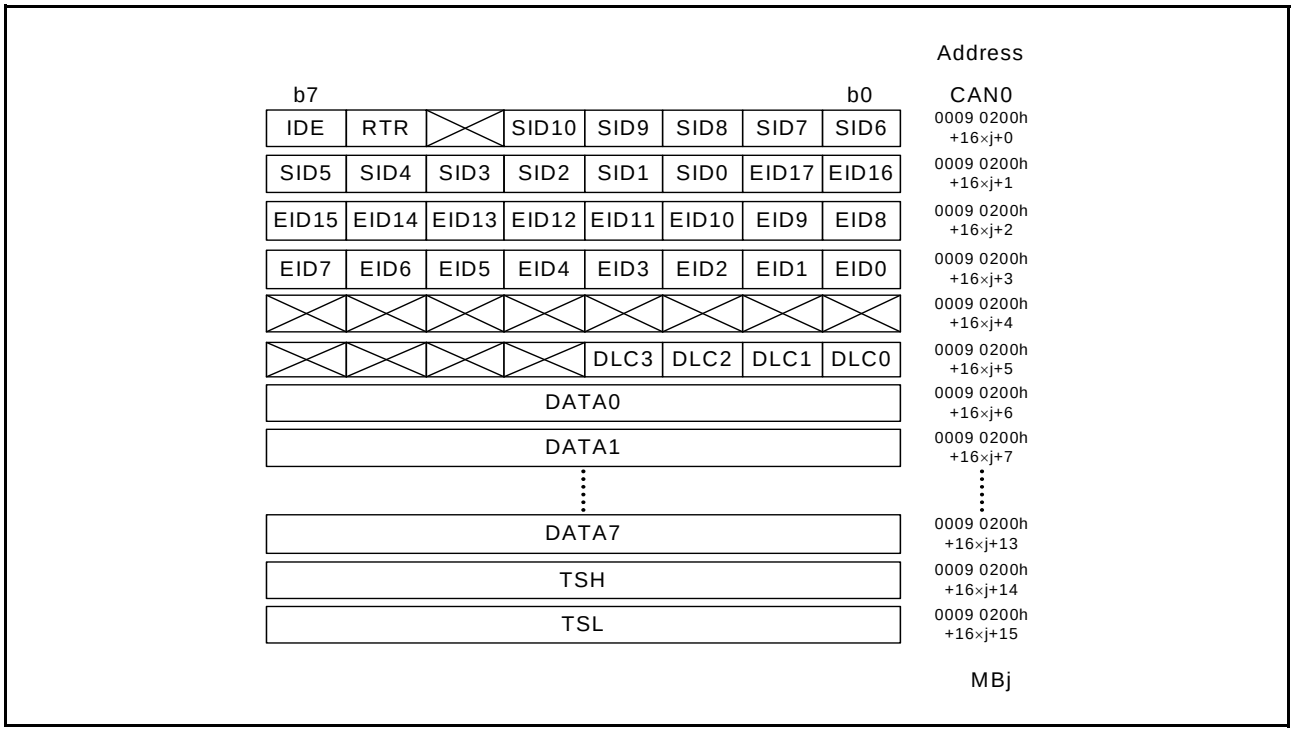


Figure 25.13 Structure of MBj (j = 0 to 31)

Figure 25.14 shows the structure of MKRi.
There are eight mask registers with the same structure.

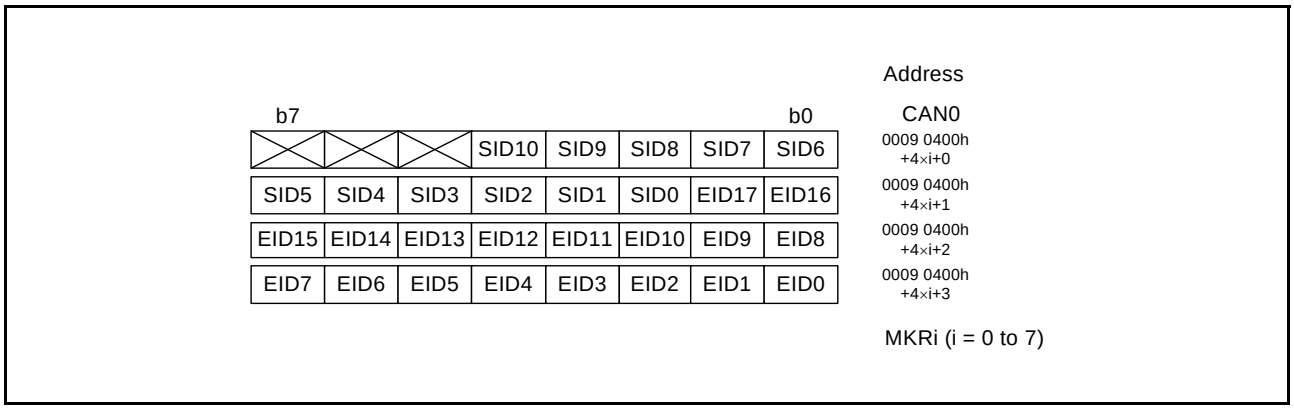


Figure 25.14 Structure of MKRi (i = 0 to 7)

Figure 25.15 shows the structure of FIDCR0 and FIDCR1.
There are two FIFO received ID compare registers with the same structure.

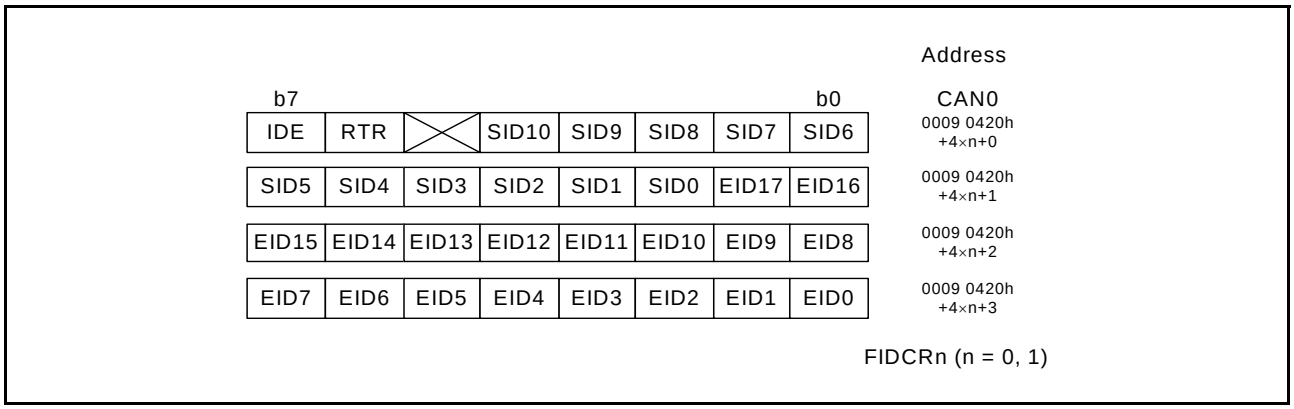


Figure 25.15 Structure of FIDCRn (n = 0, 1)

25.6 Acceptance Filtering and Masking Functions

The acceptance filtering function and masking function allows the user to receive messages with a specified range of multiple IDs for mailboxes.
Registers MKR0 to MKR7 can perform masking of the standard ID and the extended ID of 29 bits.

- MKR0 corresponds to mailboxes [0] to [3]
- MKR1 corresponds to mailboxes [4] to [7]
- MKR2 corresponds to mailboxes [8] to [11]
- MKR3 corresponds to mailboxes [12] to [15]
- MKR4 corresponds to mailboxes [16] to [19]
- MKR5 corresponds to mailboxes [20] to [23]
- MKR6 corresponds to mailboxes [24] to [27] in normal mailbox mode and the receive FIFO mailboxes [28] to [31] in FIFO mailbox mode.
- MKR7 corresponds to mailboxes [28] to [31] in normal mailbox mode and the receive FIFO mailboxes [28] to [31] in FIFO mailbox mode.

MKIVLR disables acceptance filtering individually for each mailbox.
The IDE bit in MBj is valid when the IDFM[1:0] bits in CTLR are 10 (mixed ID mode).
The RTR bit in MBj selects a data frame or a remote frame.

In FIFO mailbox mode, normal mailboxes (mailboxes [0] to [23]) use the single corresponding register among MKR0 to MKR5 for acceptance filtering. Receive FIFO mailboxes (mailboxes [28] to [31]) use two registers MKR6 and MKR7 for acceptance filtering.
Also, the receive FIFO uses two registers FIDCR0 and FIDCR1 for ID comparison. Bits EID, SID, RTR, and IDE in MB28 to MB31 for the receive FIFO are disabled. As acceptance filtering depends on the result of two logic AND operations, two ranges of IDs can be received into the receive FIFO.
MKIVLR is disabled for the receive FIFO.

If both the standard ID and extended ID are set in the IDE bits in FIDCR0 and FIDCR1 individually, both ID formats are received.
If both the data frame and remote frame are set in the RTR bits in FIDCR0 and FIDCR1 individually, both data and remote frames are received.
When combination with two ranges of IDs is not necessary, set the same mask value and the same ID into both the FIFO ID and mask register.
Figure 25.16 shows the correspondence between mask registers and mailboxes. Figure 25.17 shows acceptance filtering.

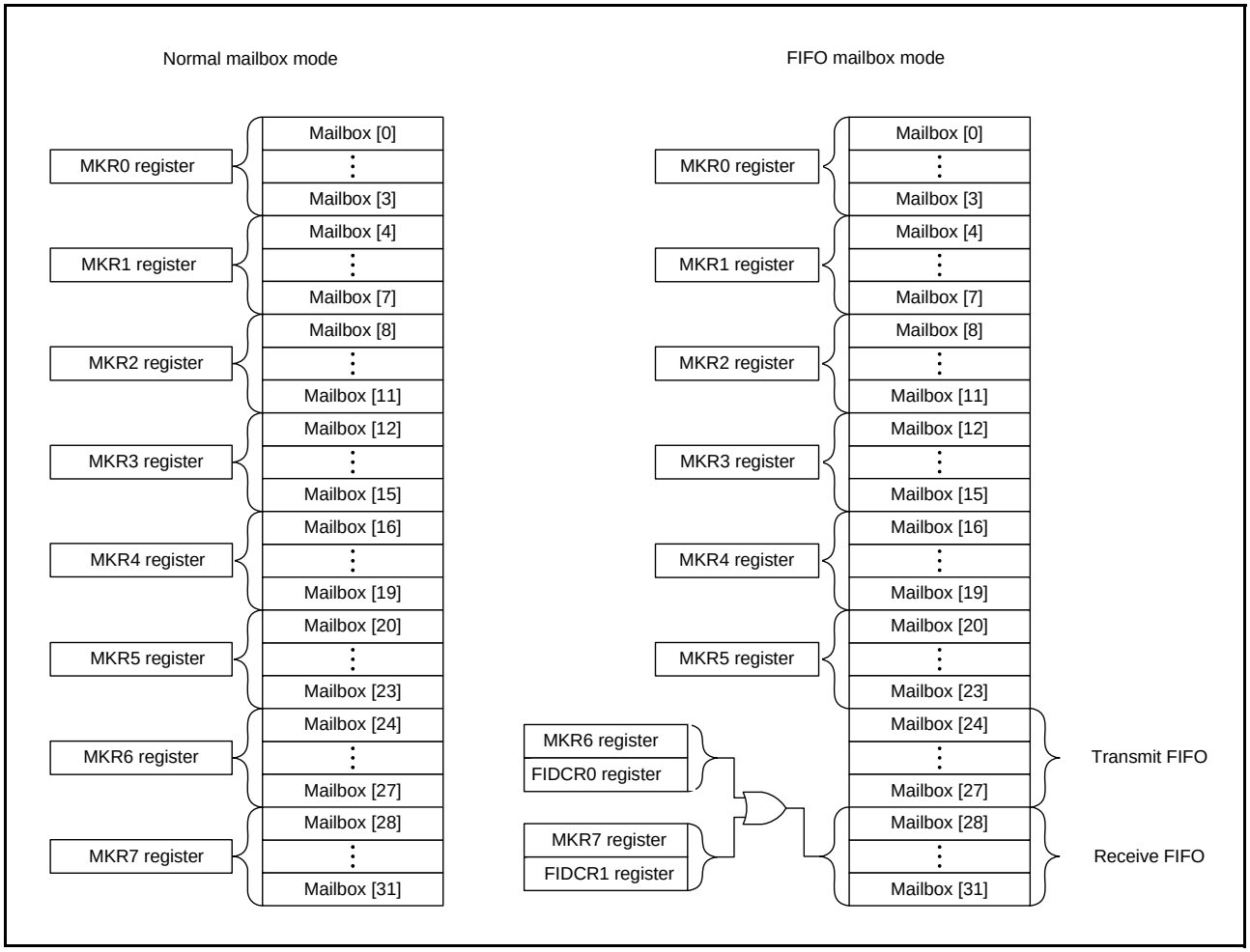


Figure 25.16 Correspondence between Mask Registers and Mailboxes

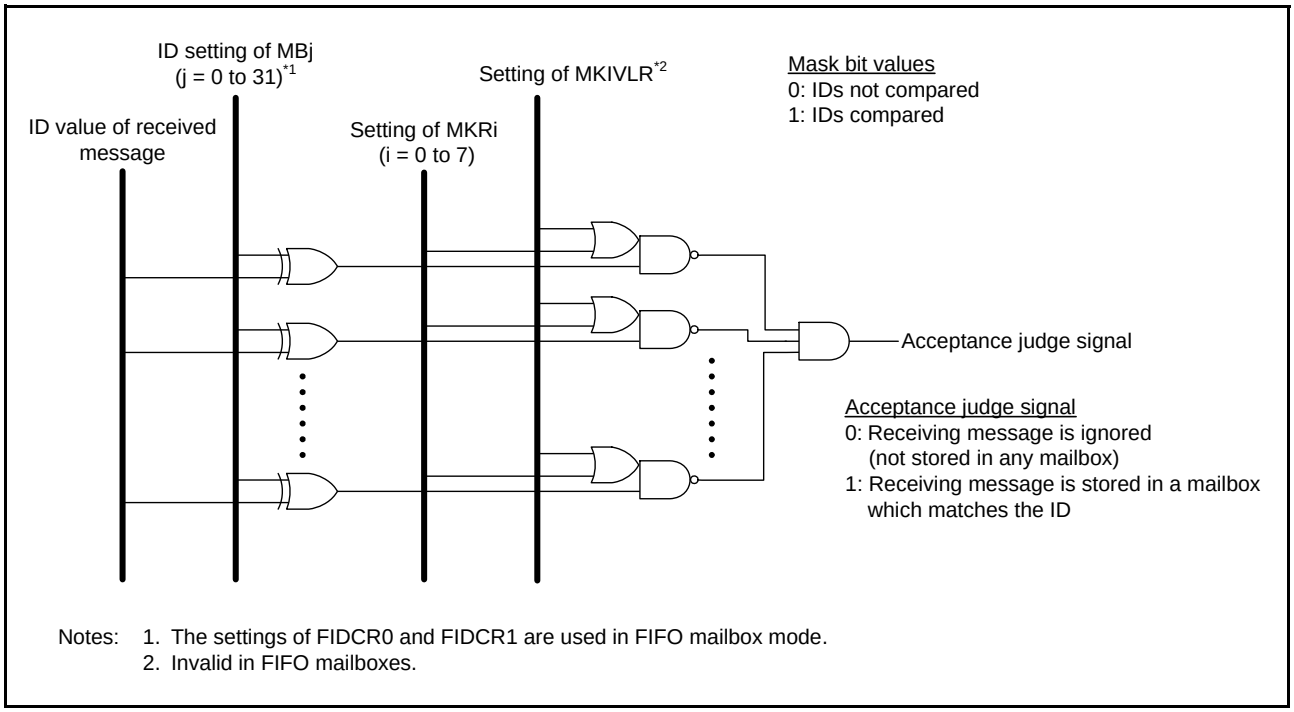


Figure 25.17 Acceptance Filtering

25.7 Reception and Transmission

Table 25.11 shows how to make the CAN communication mode settings.

Table 25.11 Setting of CAN Receive Mode and CAN Transmit Mode

MCTLj. TRMREQ	MCTLj. RECREQ	MCTLj. ONESHOT	Communication Mode of Mailbox
0	0	0	Mailbox disabled or transmission being aborted.
0	0	1	Can be configured only when transmission or reception from a mailbox programmed in one-shot mode is aborted.
0	1	0	Configured as a receive mailbox for a data frame or a remote frame.
0	1	1	Configured as a one-shot receive mailbox for a data frame or a remote frame.
1	0	0	Configured as a transmit mailbox for a data frame or a remote frame.
1	0	1	Configured as a one-shot transmit mailbox for a data frame or a remote frame.
1	1	0	Do not set.
1	1	1	Do not set.

j = 0 to 31

When a mailbox is configured as a receive mailbox or a one-shot receive mailbox, note the following:

1. Before a mailbox is configured as a receive mailbox or a one-shot receive mailbox, set MCTLj to 00h.
2. A received message is stored into the first mailbox that matches the condition according to the result of receive mode setting and acceptance filtering. Upon deciding the mailbox to store the received message, the mailbox with the smaller number has higher priority.
3. In CAN operation mode, when the CAN module transmits a message whose ID matches with the ID/mask set of a mailbox configured to receive messages, the CAN module never receives the transmitted data. In self-test mode, however, the CAN module will receive its transmitted data. In this case, the CAN module returns ACK.

When configuring a mailbox as a transmit mailbox or a one-shot transmit mailbox, note the following:

1. Before a mailbox is configured as a transmit mailbox or a one-shot transmit mailbox, ensure that MCTLj is 00h and that there is no pending abort process.

25.7.1 Reception

Figure 25.18 shows an operation example of data frame reception in overwrite mode.
This example shows the operation of overwriting the first message when the CAN module receives two consecutive CAN messages which match the receiving conditions of MCTLj (j = 0 to 31).

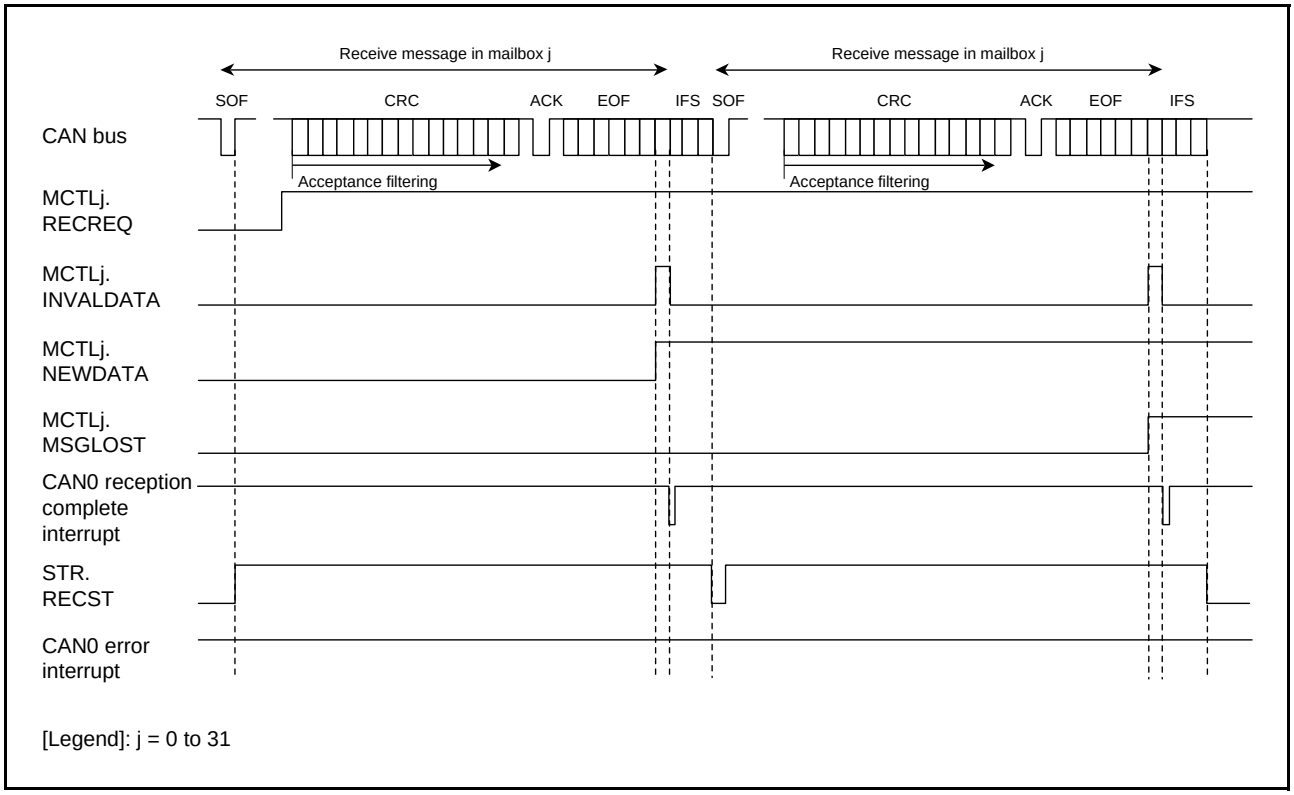


Figure 25.18 Operation Example of Data Frame Reception in Overwrite Mode

1. When an SOF is detected on the CAN bus, the RECST bit in STR is set to 1 (reception in progress) immediately if the CAN module has no message ready to start transmission.
2. The acceptance filter processing starts at the beginning of the CRC field to select the receive mailbox.
3. After a message has been received, the NEWDATA bit in MCTLj for the receive mailbox is set to 1 (new message is being stored or has been stored to the mailbox). The INVALDATA bit in MCTLj is set to 1 (message is being updated) at the same time, and then the INVALDATA bit in MCTLj is set to 0 (message valid) again after the complete message is transferred to the mailbox.
4. When the interrupt enable bit in MIER for the receive mailbox is 1 (interrupt enabled), the CAN reception complete interrupt request is generated. This interrupt (CAN reception complete interrupt) is generated when the INVALDATA bit in MCTLj is set to 0.
5. After reading the message from the mailbox, the NEWDATA flag in MCTLj needs to be set to 0 by a program.
6. In overwrite mode, if the next CAN message has been received into a mailbox whose NEWDATA flag in MCTLj is still set to 1, the MSGLOST flag in MCTLj is set to 1 (message has been overwritten). The new received message is transferred to the mailbox. The CAN reception complete interrupt request is generated the same as in 4.

Figure 25.19 shows the operation example of data frame reception in overrun mode.
This example shows the operation of overrunning the second message when the CAN module receives two consecutive CAN messages which match the receiving conditions of MCTLj (j = 0 to 31).

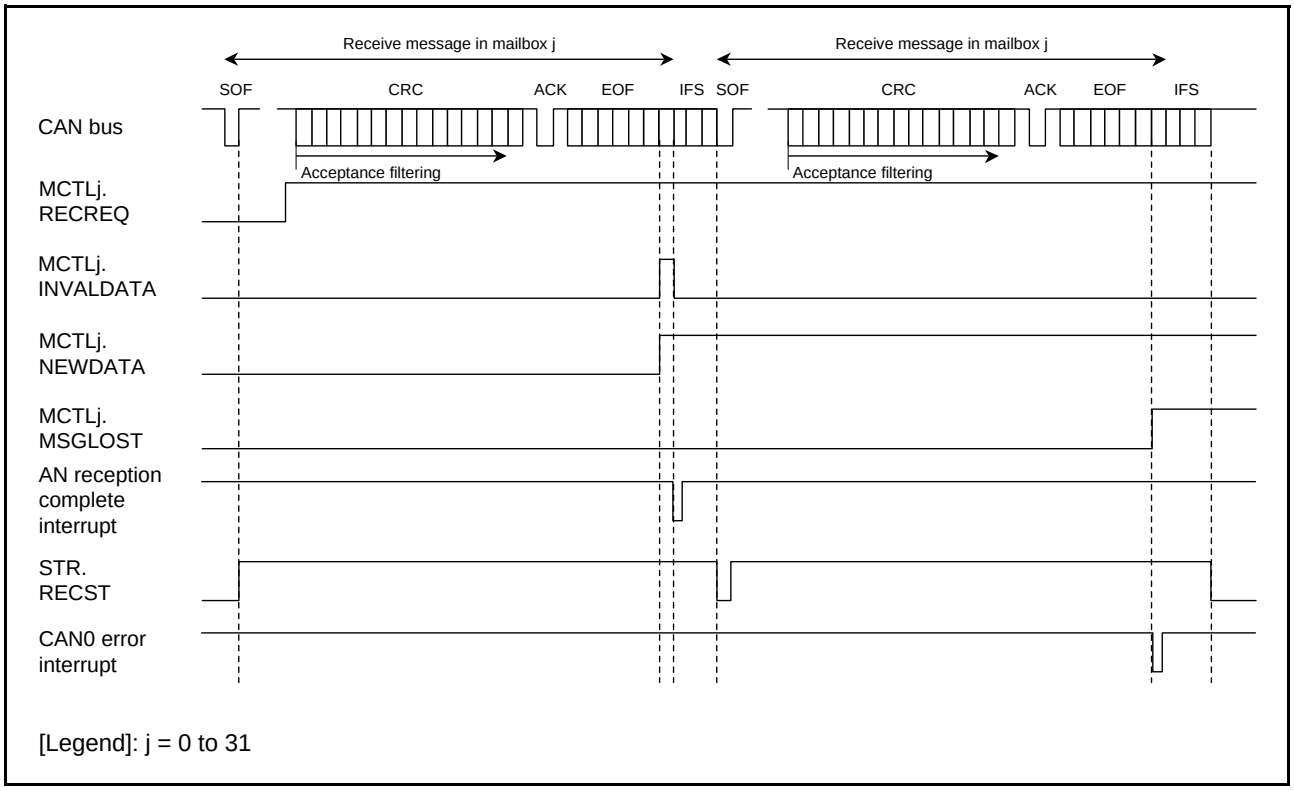


Figure 25.19 Operation Example of Data Frame Reception in Overrun Mode

1. to 5. are the same as in overwrite mode.

6. In overrun mode, if the next CAN message has been received before the NEWDATA flag in MCTLj is set to 0, the MSGLOST flag in MCTLj is set to 1 (message has been overrun). The new received message is discarded and a CAN error interrupt request is generated if the corresponding interrupt enable bit in EIER is set to 1 (interrupt enabled).

25.7.2 Transmission

Figure 25.20 shows an operation example of data frame transmission.

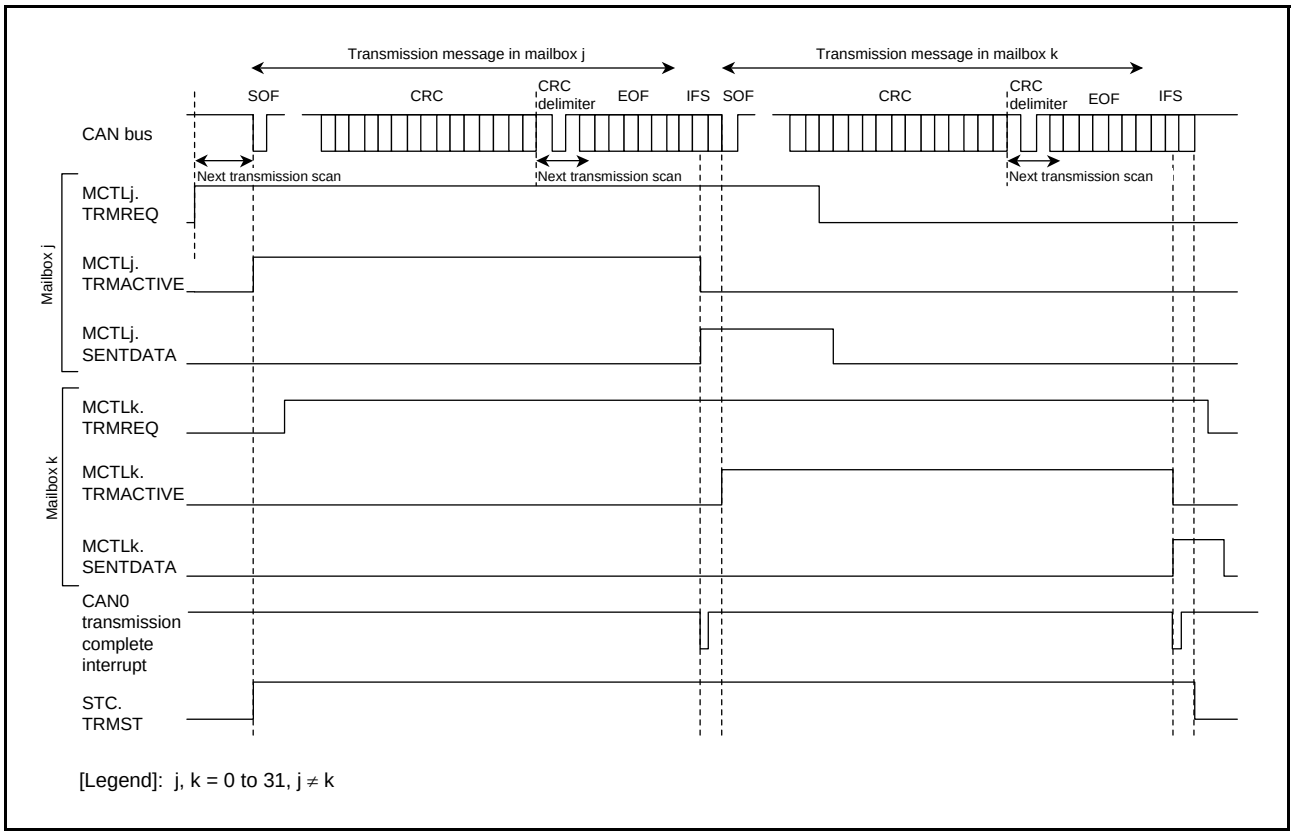


Figure 25.20 Operation Example of Data Frame Transmission

1. When a TRMREQ bit in MCTLj (j = 0 to 31) is set to 1 (transmit mailbox) in the bus-idle state, the mailbox scan processing starts to decide the highest-priority mailbox for transmission. Once the transmit mailbox is decided, the TRMACTIVE bit in MCTLj is set to 1 (from acceptance of transmission request to completion of transmission, or error/arbitration lost), the TRMST flag in STR is set to 1 (transmission in progress), and the CAN module starts transmission.*
2. If other TRMREQ bits in MCTLj are set, the transmission scan processing starts with the CRC delimiter for the next transmission.
3. If transmission is completed without losing arbitration, the SENTDATA flag in MCTLj is set to 1 (transmission completed) and the TRMACTIVE bit in MCTLj is set to 0 (transmission is pending or transmission is not requested). If the interrupt enable bit in MIER is 1 (interrupt enabled), the CAN transmission complete interrupt request is generated.
4. When requesting the next transmission from the same mailbox, set SENDTDATA flag and TRMREQ bit in MCTLj to 0, then set the TRMREQ bit to 1 after checking that SENDTDATA flag and TRMREQ bit in MCTLj have been set to 0.

Note 1. If arbitration is lost after the CAN module starts transmission, the TRMACTIVE bit in MCTLj is set to 0. The transmission scan processing is performed again to search for the highest-priority transmit mailbox from the beginning of the CRC delimiter. If an error occurs either during transmission or following the arbitration lost, the transmission scan processing is performed again to search for the highest-priority transmit mailbox from the start of the error delimiter.

25.8 CAN Interrupt

The CAN module provides the following CAN interrupts for each channel. Table 25.12 lists CAN interrupts.

- CAN0 reception complete interrupt (mailboxes 0 to 31) [RXM0]
- CAN0 transmission complete interrupt (mailboxes 0 to 31) [TXM0]
- CAN0 receive FIFO interrupt [RXF0]
- CAN0 transmit FIFO interrupt [TXF0]
- CAN0 error interrupt [ERS0]

There are eight types of interrupt sources for the CAN0 error interrupts. These sources can be determined by checking EIFR.

- Bus error
- Error-warning
- Error-passive
- Bus-off entry
- Bus-off recovery
- Receive overrun
- Overload frame transmission
- Bus lock

Table 25.12 CAN Interrupts

Module	Interrupt Symbol	Interrupt Source	Source Flag
CAN0	ERS0	Bus lock detected	EIFR.BLIF
		Overload frame transmission detected	EIFR.OLIF
		Overrun detected	EIFR.ORIF
		Bus-off recovery detected	EIFR.BORIF
		Bus-off entry detected	EIFR.BOEIF
		Error-passive detected	EIFR.EPIF
		Error-warning detected	EIFR.EWIF
		Bus error detected	EIFR.BEIF
	RXF0	Receive FIFO message received (MIER[29] = 0)	—
		Receive FIFO warning (MIER[29] = 1)	
	TXF0	Transmit FIFO message transmission completed (MIER[25] = 0)	—
		FIFO last message transmission completed (MIER[25] = 1)	
	RXM0	Mailbox 0 to 31 message received	MCTL0.NEWDATA to MCTL31.NEWDATA
	TXM0	Mailbox 0 to 31 message transmission completed	MCTL0.SENTDATA to MCTL31.SENTDATA

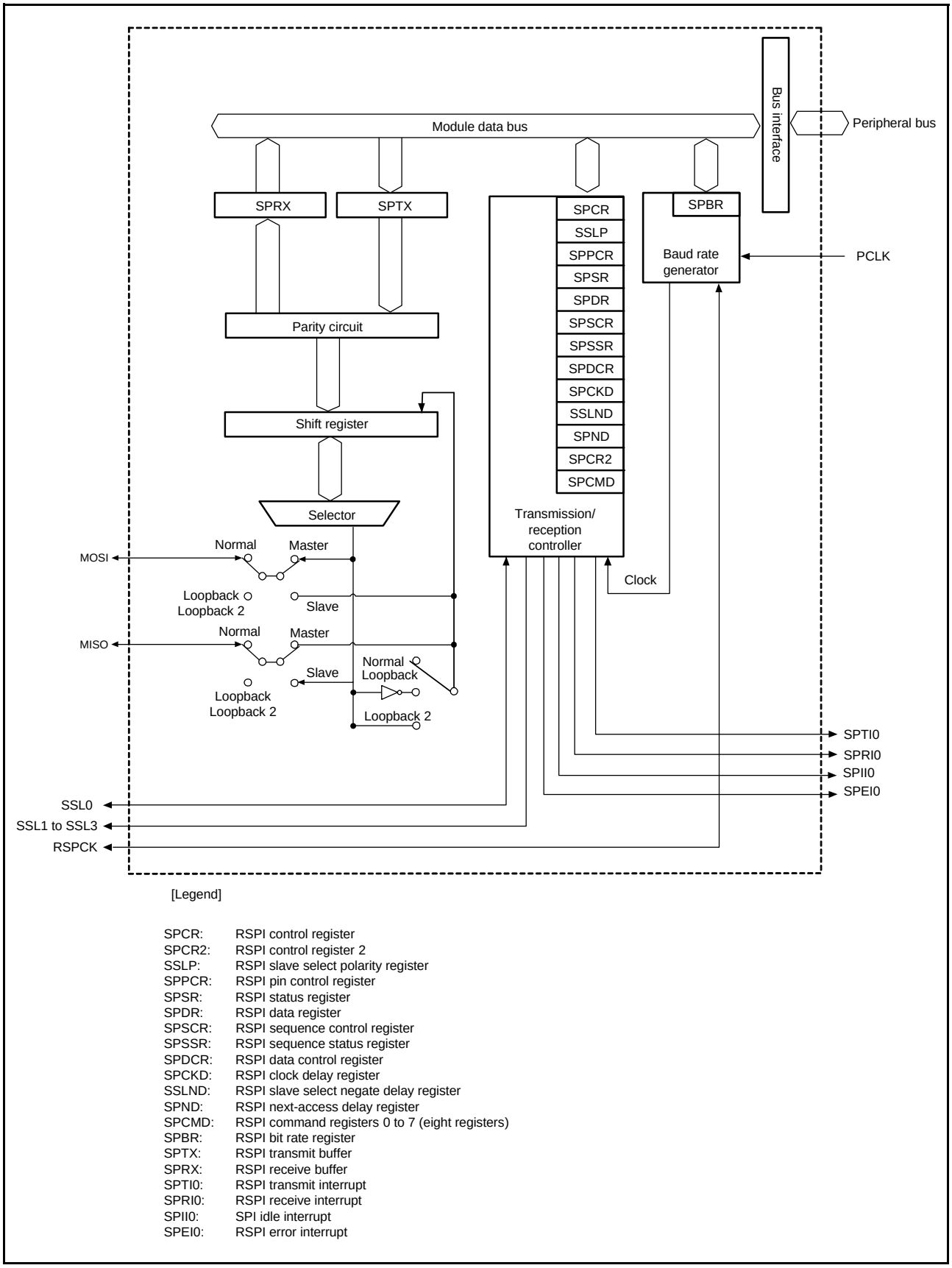
26. Serial Peripheral Interface (RSPI)

26.1 Overview

The RX62T Group includes one independent channel of Serial Peripheral Interface (RSPI).
The RSPI channels are capable of full-duplex high-speed serial communications with multiple processors and peripheral devices.
Table 26.1 shows the specifications of the RSPI, and Figure 26.1 shows a block diagram of the RSPI.

Table 26.1 Specifications of RSPI

Item	Description
Number of channels	One channel
RSPI transfer functions	• Use of MOSI (master out/slave in), MISO (master in/slave out), SSL (slave select), and RSPCK (RSPI clock) signals allows serial communications through SPI operation (four-wire method) or clock synchronous operation (three-wire method). • Transmit-only operation is available. • Capable of serial communications in master/slave mode • Switching of the polarity of the serial transfer clock • Switching of the phase of the serial transfer clock
Data format	• MSB-first/LSB-first selectable • Transfer bit length is selectable as 8, 9, 10, 11, 12, 13, 14, 15, 16, 20, 24, or 32 bits. • 128-bit transmit/receive buffers • Up to four frames can be transferred in one round of transmission/reception (each frame consisting of up to 32 bits).
Buffer configuration	• Double buffer configuration for the transmit/receive buffers
Error detection	• Mode fault error detection • Overrun error detection • Parity error detection
SSL control function	• Four SSL signals (SSLn0 to SSLn3) for each channel • In single-master mode, SSL0 to SSL3 signals are output. • In multi-master mode: SSL0 signal for input, and SSL1 to SSL3 signals for either output or high-impedance. • In slave mode: SSL0 signal for input, and SSL1 to SSL3 signals for high-impedance. • Controllable delay from SSL output assertion to RSPCK operation (RSPCK delay) Range: 1 to 8 RSPCK cycles (set in RSPCK-cycle units) • Controllable delay from RSPCK stoppage to SSL output negation (SSL negation delay) Range: 1 to 8 RSPCK cycles (set in RSPCK-cycle units) • Controllable wait for next-access SSL output assertion (next-access delay) Range: 1 to 8 RSPCK cycles (set in RSPCK-cycle units) • Function for changing SSL polarity
Control in master transfer	• A transfer of up to eight commands can be executed sequentially in looped execution. • For each command, the following can be set: SSL signal value, bit rate, RSPCK polarity/phase, transfer data length, LSB/MSB-first, burst, RSPCK delay, SSL negation delay, and next-access delay • A transfer can be initiated by writing to the transmit buffer. • MOSI signal value specifiable in SSL negation
Interrupt sources	• Maskable interrupt sources RSPI receive interrupt (receive buffer full) RSPI transmit interrupt (transmit buffer empty) RSPI error interrupt (mode fault, overrun, parity error) RSPI idle interrupt (RSPI idle)
Others	• Function for disabling (initializing) the RSPI • Loopback mode



[Legend]

SPCR:	RSPI control register
SPCR2:	RSPI control register 2
SSLP:	RSPI slave select polarity register
SPPCR:	RSPI pin control register
SPSR:	RSPI status register
SPDR:	RSPI data register
SPSCR:	RSPI sequence control register
SPSSR:	RSPI sequence status register
SPDCR:	RSPI data control register
SPCKD:	RSPI clock delay register
SSLND:	RSPI slave select negate delay register
SPND:	RSPI next-access delay register
SPCMD:	RSPI command registers 0 to 7 (eight registers)
SPBR:	RSPI bit rate register
SPTX:	RSPI transmit buffer
SPRX:	RSPI receive buffer
SPTI0:	RSPI transmit interrupt
SPRI0:	RSPI receive interrupt
SPII0:	SPI idle interrupt
SPEI0:	RSPI error interrupt

Figure 26.1 Block Diagram of RSPI

Table 26.2 shows the input and output pins used in the RSPI.
The RSPI automatically switches the input/output direction of the SSL0 pin. SSL0 is set as an output when the RSPI is a single master and as an input when the RSPI is a multi-master or a slave. Pins RSPCK, MOSI, and MISO are automatically set as inputs or outputs according to the setting of master or slave and the level input on the SSL0 pin (see section 26.3.2, Controlling RSPI Pins).

Table 26.2 RSPI Pin Configuration

Module Symbol	Pin Name	I/O	Function
RSPI0	RSPCK	I/O	Clock input/output pin
	MOSI	I/O	Master transmit data input/output pin
	MISO	I/O	Slave transmit data input/output pin
	SSL0	I/O	Slave selection input/output pin
	SSL1	Output	Slave selection output pin
	SSL2	Output	Slave selection output pin
	SSL3	Output	Slave selection output pin

26.2 Register Descriptions

Table 26.3 shows a list of the RSPI registers. These registers enable the RSPI to perform the following controls: specifying master/slave modes, specifying a transfer format, and controlling the transmitter and receiver.

Table 26.3 Registers of RSPI

Module Symbol	Register Name	Symbol	Value after Reset	Address	Access Size
RSPI0	RSPI control register	SPCR	00h	0008 8380h	8
	RSPI slave select polarity register	SSLP	00h	0008 8381h	8
	RSPI pin control register	SPPCR	00h	0008 8382h	8
	RSPI status register	SPSR	20h	0008 8383h	8
	RSPI data register	SPDR	00000000h	0008 8384h	16, 32
	RSPI sequence control register	SPSCR	00h	0008 8388h	8
	RSPI sequence status register	SPSSR	00h	0008 8389h	8
	RSPI bit rate register	SPBR	FFh	0008 838Ah	8
	RSPI data control register	SPDCR	00h	0008 838Bh	8
	RSPI clock delay register	SPCKD	00h	0008 838Ch	8
	RSPI slave select negation delay register	SSLND	00h	0008 838Dh	8
	RSPI next-access delay register	SPND	00h	0008 838Eh	8
	RSPI control register 2	SPCR2	00h	0008 838Fh	8
	RSPI command register 0	SPCMD0	070Dh	0008 8390h	16
	RSPI command register 1	SPCMD1	070Dh	0008 8392h	16
	RSPI command register 2	SPCMD2	070Dh	0008 8394h	16
	RSPI command register 3	SPCMD3	070Dh	0008 8396h	16
	RSPI command register 4	SPCMD4	070Dh	0008 8398h	16
	RSPI command register 5	SPCMD5	070Dh	0008 839Ah	16
	RSPI command register 6	SPCMD6	070Dh	0008 839Ch	16
	RSPI command register 7	SPCMD7	070Dh	0008 839Eh	16

x: Undefined

26.2.1 RSPI Control Register (SPCR)

Address: 0008 8380h

	b7	b6	b5	b4	b3	b2	b1	b0
	SPRIE	SPE	SPTIE	SPEIE	MSTR	MODFEN	TXMD	SPMS
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	SPMS	RSPI Mode Select	0: SPI operation (four-wire method) 1: Clock synchronous operation (three-wire method)	R/W
b1	TXMD	Communications Operating Mode Select	0: Full-duplex synchronous serial communications 1: Serial communications consisting of only transmit operations	R/W
b2	MODFEN	Mode Fault Error Detection Enable	0: Disables the detection of mode fault error 1: Enables the detection of mode fault error	R/W
b3	MSTR	RSPI Master/Slave Mode Select	0: Slave mode 1: Master mode	R/W
b4	SPEIE	RSPI Error Interrupt Enable	0: Disables the generation of RSPI error interrupt requests 1: Enables the generation of RSPI error interrupt requests	R/W
b5	SPTIE	RSPI Transmit Interrupt Enable	0: Disables the generation of RSPI transmit interrupt requests 1: Enables the generation of RSPI transmit interrupt requests	R/W
b6	SPE	RSPI Function Enable	0: Disables the RSPI function 1: Enables the RSPI function	R/W
b7	SPRIE	RSPI Receive Interrupt Enable	0: Disables the generation of RSPI receive interrupt requests 1: Enables the generation of RSPI receive interrupt requests	R/W

SPCR sets the operating mode of the RSPI. If the SPCR.MSTR, SPCR.MODFEN, and SPCR.TXMD bits are changed while the RSPI function is enabled (SPCR.SPE = 1), subsequent operations cannot be guaranteed.

SPMS Bit (RSPI Mode Select)

The SPMS bit selects SPI operation (four-wire method) or clock synchronous operation (three-wire method).
The SSL0 to SSL3 pins are not used in clock synchronous operation. The three pins RSPCK, MOSI, and MISO handle communications. If clock-synchronous operation is to proceed in master mode (SPCR.MSTR = 1), the CPHA bit in the RSPI command register (SPCMD) can be set to either 0 or 1. Set the SPCMD.CPHA bit to 1 if clock-synchronous operation is to proceed in slave mode (SPCR.MSTR = 0). Operation is not guaranteed if the SPCMD.CPHA bit is set to 0 when clock-synchronous operation is to proceed in slave mode (SPCR.MSTR = 0).

TXMD Bit (Communications Operating Mode Select)

The TXMD bit selects full-duplex synchronous serial communications or transmit operations only.
When performing communications with the TXMD bit set to 1, the RSPI performs only transmit operations and not receive operations (see section 26.3.6, Communications Operating Mode).
When the TXMD bit is set to 1, receive buffer full interrupt requests cannot be used.

MODFEN Bit (Mode Fault Error Detection Enable)

The MODFEN bit enables or disables the detection of mode fault error (see section 26.3.8, Error Detection). In addition, the RSPI determines the input/output direction of the SSL0 to SSL3 pins based on combinations of the MODFEN and MSTR bits (see section 26.3.2, Controlling RSPI Pins).

MSTR Bit (RSPI Master/Slave Mode Select)

The MSTR bit selects master/slave mode of the RSPI. According to MSTR bit settings, the RSPI determines the direction of pins RSPCK, MOSI, MISO.

SPEIE Bit (RSPI Receive Interrupt Enable)

The SPEIE bit enables or disables the generation of RSPI error interrupt requests when the RSPI detects a mode fault error and sets the SPSR.MODF bit to 1, or when the RSPI detects an overrun error and sets the SPSR.OVRF flag to 1 (see section 26.3.8, Error Detection).

SPTIE Bit (RSPI Transmit Interrupt Enable)

The SPTIE bit enables or disables the generation of RSPI transmit interrupt requests when the RSPI detects transmit buffer empty.

At the beginning of transmission, the transmit interrupt requests are generated by setting the SPE bit to 1 at the same time or after the SPTIE bit has been set to 1.

Therefore, note that even while the RSPI function is disabled (SPE bit is 0), setting the SPTIE bit to 1 will generate an RSPI transmit interrupt request.

SPE Bit (RSPI Function Enable)

The SPE bit enables or disables the RSPI function. When the SPSR.MODF flag is 1, the SPE bit cannot be set to 1. For details, refer to section 26.3.8, Error Detection.

Setting the SPE bit to 0 disables the RSPI function, and initializes a part of the module function. For details, refer to section 26.3.9, Initializing RSPI.

SPRIE Bit (RSPI Error Interrupt Enable)

If the RSPI has detected a receive buffer write after completion of a serial transfer, the SPRIE bit enables or disables the generation of an RSPI receive interrupt request.

26.2.2 RSPI Slave Select Polarity Register (SSLP)

Address: 0008 8381h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	SSL3P	SSL2P	SSL1P	SSL0P
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	SSL0P	SSL0 Signal Polarity Setting	0: SSL0 signal is 0-active 1: SSL0 signal is 1-active	R/W
b1	SSL1P	SSL1 Signal Polarity Setting	0: SSL1 signal is 0-active 1: SSL1 signal is 1-active	R/W
b2	SSL2P	SSL2 Signal Polarity Setting	0: SSL2 signal is 0-active 1: SSL2 signal is 1-active	R/W
b3	SSL3P	SSL3 Signal Polarity Setting	0: SSL3 signal is 0-active 1: SSL3 signal is 1-active	R/W
b7 to b4	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

SSLP sets the polarity of the SSL0 to SSL3 signals of the RSPI.
If the contents of SSLP are changed by the CPU while the RSPI function is enabled (SPCR.SPE = 1), subsequent operations are not guaranteed.

SSLiP Bit (SSL Signal Polarity Setting) (i = 0 to 3)

These bits set the polarity of the SSLi signals. The setting of SSLiP indicates the active polarity of the SSLi signal.

26.2.3 RSPI Pin Control Register (SPPCR)

Address: 0008 8382h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	MOIFE	MOIFV	—	—	SPLP2	SPLP
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	SPLP	RSPI Loopback	0: Normal mode 1: Loopback mode (reversed transmit data = receive data)	R/W
b1	SPLP2	RSPI Loopback 2	0: Normal mode 1: Loopback mode (transmit data = receive data)	R/W
b3, b2	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b4	MOIFV	MOSI Idle Fixed Value	0: MOSI Idle fixed value equals 0 1: MOSI Idle fixed value equals 1	R/W
b5	MOIFE	MOSI Idle Value Fixing Enable	0: MOSI output value equals final data from previous transfer 1: MOSI output value equals the value set in the MOIFV bit	R/W
b7, b6	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

SPPCR sets the modes of the RSPI pins. If the contents of SPPCR are changed by the CPU while the RSPI function is enabled (SPCR.SPE = 1), subsequent operations are not guaranteed.

SPLP Bit (RSPI Loopback)

The SPLP bit selects the mode of the RSPI pins.

When the SPLP bit is set to 1, the RSPI shuts off the path between the MISO pin and the shift register if the SPCR.MSTR bit is 1, and between the MOSI pin and the shift register if the SPCR.MSTR bit is 0, and connects (reverses) the input path and output path for the shift register (loopback mode). For details, see section 26.3.13, Loopback Mode.

SPLP2 Bit (RSPI Loopback 2)

The SPLP2 bit selects the mode of the RSPI pins.

When the SPLP2 bit is set to 1, the RSPI shuts off the path between the MISO pin and the shift register if the SPCR.MSTR bit is 1, and between the MOSI pin and the shift register if the SPCR.MSTR bit is 0, and connects the input path and output path for the shift register (loopback mode 2). For details, see section 26.3.13, Loopback Mode.

MOIFV Bit (MOSI Idle Fixed Value)

If the MOIFE bit is 1 in master mode, the MOIFV bit determines the MOSI pin output value during the SSL negation period (including the SSL retention period during a burst transfer).

MOIFE Bit (MOSI Idle Value Fixing Enable)

The MOIFE bit fixes the MOSI output value when the RSPI in master mode is in an SSL negation period (including the SSL retention period during a burst transfer). When the MOIFE bit is 0, the RSPI outputs the last data from the previous serial transfer during the SSL negation period. When the MOIFE bit is 1, the RSPI outputs the fixed value set in the MOIFV bit to the MOSI bit.

26.2.4 RSPI Status Register (SPSR)

Address: 0008 8383h

	b7	b6	b5	b4	b3	b2	b1	b0
	SPRF	—	SPTEF	—	PERF	MODF	IDLNF	OVRF
Value after reset:	0	0	1	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	OVRF	Overrun Error Flag	0: No overrun error occurs 1: An overrun error occurs	R/(W)*1
b1	IDLNF	RSPI Idle Flag	0: RSPI is in the idle state 1: RSPI is in the transfer state	R
b2	MODF	Mode Fault Error Flag	0: No mode fault error occurs 1: A mode fault error occurs	R/(W)*1
b3	PERF	Parity Error Flag	0: No parity error occurs 1: A parity error occurs	R/(W)*1
b4	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b5	SPTEF	Transmit Buffer Empty Flag	0: When data is transferred to SPDR (Transmit buffer is full) 1: When data is transferred from SPDR to shift register (Transmit buffer is empty)	R/(W)*2
b6	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b7	SPRF	Receive Buffer Full Flag	0: When data is transferred from SPDR (SPDR has no valid received data) 1: When data has been received normally and transferred from shift register to SPDR (SPDR has valid received data)	R/(W)*2

Note 1. Only 0 can be written to clear the flag after reading 1.
Note 2. The write value should always be 1.

SPSR indicates the operating status of the RSPI. SPSR can always be read by the CPU. Writing to SPSR can only be performed by the CPU under certain conditions.

OVRF Flag (Overrun Error Flag)

The OVRF flag indicates the occurrence of an overrun error.
[Setting condition]

- If a serial transfer ends while the SPCR.TXMD bit is 0 and the receive buffer holds data that has not yet been read out

[Clearing condition]

- The CPU reads SPSR when the OVRF flag is 1, and then writes the value 0 to the OVRF flag.

IDLNF Flag (RSPI Idle Flag)

The IDLNF flag indicates the transfer status of the RSPI.
[Setting condition]
<Master mode>

- Even one condition among the following clearing conditions for master mode is not satisfied

<Slave mode>

- The SPCR.SPE bit is 1 (RSPI function is enabled)

[Clearing conditions]
<Master mode>

- The SPCR.SPE bit is 0 (RSPI is initialized)
- The transmit buffer (SPTX) is empty (data for the next transfer is not set)
- The SPSSR.SPCP[2:0] bits are 000 (beginning of sequence control)
- The RSPI internal sequencer has entered the idle state (status in which operations up to the next-access delay have finished)

The flag is cleared to 0 when the above first clearing condition is satisfied or all of the second to fourth clearing conditions are satisfied.
<Slave mode>

- The SPCR.SPE bit is 0 (RSPI is initialized)

MODF Flag (Mode Fault Error Flag)

Indicates the occurrence of a mode fault error.
[Setting condition]
<Multi-master mode>

- When the input level of the SSL pin changes to the active level while the SPCR.MSTR bit is 1 (master mode) and the SPCR.MODFEN bit is 1 (mode fault error detection is enabled), the RSPI detects a mode fault error

<Slave mode>

- When the SSL pin is negated before the RSPCK cycle necessary for data transfer ends while the SPCR.MSTR bit is 0 (slave mode) and the SPCR.MODFEN bit is 1 (mode fault error detection is enabled), the RSPI detects a mode fault error

The active level of the SSL signal is determined by the SSLP.SSLiP bit (SSL signal polarity setting bit).(i = 0 to 3)

[Clearing condition]

- The CPU reads SPSR when the MODF flag is 1, and then writes the value 0 to the MODF flag

PERF Flag (Parity Error Flag)

Indicates the occurrence of a parity error.
[Setting condition]

- When a serial transfer ends while the SPCR.TXMD bit is 0 and the SPCR2.SPPE bit is 1, the RSPI detects a parity error

[Clearing condition]

- The CPU reads SPSR when the PERF flag is 1, and then writes the value 0 to the PERF flag

SPTEF Flag (Transmit Buffer Empty Flag)

Indicates whether the transmit buffer is empty.
[Setting condition]

- When data is transferred from SPDR to shift register

[Clearing condition]

- When data is transferred to SPDR

SPRF Flag (Receive Buffer Full Flag)

Indicates whether the receive buffer is full.
[Setting condition]

- When data has been received normally and transferred from shift register to SPDR

[Clearing condition]

- When data is transferred from SPDR

26.2.5 RSPI Data Register (SPDR)

Address: 0008 8384h

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
	H[15:0]															
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	L[15:0]															
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SPDR which can always be read from or written to by the CPU is a buffer that holds data for transmission and reception by the RSPI.

The transmit buffer (SPTX) and receive buffer (SPRX) are independent and are mapped to SPDR.

Reading from or writing to SPDR should be performed in word or longword units according to the SPDCR.SPLW bit setting. When the SPLW bit is 0, SPDR is a 64-bit buffer that consists of up to four 16-bit frames. When the SPLW bit is 1, SPDR is a 128-bit buffer that consists of up to four 32-bit frames.

The frame length used by SPDR is determined by the number of frames specification bits (SPDCR.SPFC[1:0]), and the bit length to be used is determined by the RSPI data length specification bits (SPCMD.SPB[3:0]).

If the transmit buffer (SPTX) is empty (data for the next transfer is not set) when data is written to SPDR, the RSPI allows writing of the data to the transmit buffer of SPDR. If the transmit buffer holds data that has not yet been transmitted, the RSPI does not allow updating of the transmit buffer of SPDR.

If the SPDCR.SPRDTD bit is 0 when data is read from SPDR, the RSPI allows reading of the receive buffer. If the SPDCR.SPRDTD bit is 1, the RSPI allows reading of the transmit buffer.

When reading from the transmit buffer, the value written to the buffer immediately before the read operation is read. If the transmit buffer holds data that has not yet been transmitted, the data read out will be 0.

In the normal operation method, data is read from the receive buffer when the SPRDTD bit is 0 and a receive buffer full interrupt occurs. When the receive buffer holds data that has not yet been read out or the SPSR.OVRF flag is 1, the RSPI does not update the receive buffer of SPDR at the end of a serial transfer.

To read from or write to the SPDR register in words or longwords, access the following addresses. Otherwise, the data is not guaranteed.

- Longwords: RSPI.SPDR 0008 8384h
- Words: RSPI.SPDR 0008 8384h

26.2.6 RSPI Sequence Control Register (SPSCR)

Address: 0008 8388h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	SPSLN[2:0]		
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b2 to b0	SPSLN[2:0]	RSPI Sequence Length Specification	b2 b1 b0 Sequence Length / Referenced SPCMD0 to SPCMD7 (No.) 0 0 0: 1 — 0 → 0 → … 0 0 1: 2 — 0 → 1 → 0 → … 0 1 0: 3 — 0 → 1 → 2 → 0 → … 0 1 1: 4 — 0 → 1 → 2 → 3 → 0 → … 1 0 0: 5 — 0 → 1 → 2 → 3 → 4 → 0 → … 1 0 1: 6 — 0 → 1 → 2 → 3 → 4 → 5 → 0 → … 1 1 0: 7 — 0 → 1 → 2 → 3 → 4 → 5 → 6 → 0 → … 1 1 1: 8 — 0 → 1 → 2 → 3 → 4 → 5 → 6 → 7 → 0 → … SPCMD0 to SPCMD7 to be referenced and the order in which they are referenced are changed according to the sequence length that is set in these bits. The relationship among the setting of these bits, sequence length, and SPCMD0 to SPCMD7 referenced by the RSPI is shown below. However, the RSPI in slave mode always references SPCMD0.	R/W
b7 to b3	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

SPSCR sets the sequence control method when the RSPI operates in master mode. When changing the SPSCR.SPSLN[2:0] bits while both the SPCR.MSTR and SPCR.SPE bits are 1, the bits should be changed while the SPSR.IDLNF flag is 0.

SPSLN[2:0] Bits (RSPI Sequence Length Specification)

The SPSLN[2:0] bits specify a sequence length when the RSPI in master mode performs sequential operations. The RSPI in master mode changes RSPI command registers 0 to 7 (SPCMD0 to SPCMD7) to be referenced and the order in which they are referenced according to the sequence length that is set in the SPSLN[2:0] bits.
The RSPI in slave mode always references SPCMD0.

26.2.7 RSPI Sequence Status Register (SPSSR)

Address: 0008 8389h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	SPECM[2:0]			—	SPCP[2:0]		
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b2 to b0	SPCP[2:0]	RSPI Command Pointer	b2 b1 b0 0 0 0: SPCMD0 0 0 1: SPCMD1 0 1 0: SPCMD2 0 1 1: SPCMD3 1 0 0: SPCMD4 1 0 1: SPCMD5 1 1 0: SPCMD6 1 1 1: SPCMD7	R
b3	—	Reserved	This bit is always read as 0. Writing to this bit has no effect.	R/W
b6 to b4	SPECM[2:0]	RSPI Error Command	b6 b5 b4 0 0 0: SPCMD0 0 0 1: SPCMD1 0 1 0: SPCMD2 0 1 1: SPCMD3 1 0 0: SPCMD4 1 0 1: SPCMD5 1 1 0: SPCMD6 1 1 1: SPCMD7	R
b7	—	Reserved	This bit is always read as 0. Writing to this bit has no effect.	R/W

SPSSR indicates the sequence control status when the RSPI operates in master mode.
Any writing to SPSSR by the CPU is ignored.

SPCP[2:0] Bits (RSPI Command Pointer)

The SPCP[2:0] bits indicate SPCMD0 to SPCMD7 that is currently pointed to by the pointer during sequence control by the RSPI.
For the RSPI's sequence control, see section 26.3.10.1, Master Mode Operation.

SPECM[2:0] Bits (RSPI Error Command)

The SPECM[2:0] bits indicate SPCMD0 to SPCMD7 that is specified by the SPCP[2:0] bits when an error is detected during sequence control by the PERF. The RSPI updates the SPECM[2:0] bits only when an error is detected. If the OVRF, MODF, and PERF bits in SPSR are all 0 and there is no error, the values of the SPECM[2:0] bits have no meaning.
For the RSPI's error detection function, see section 26.3.8, Error Detection. For the RSPI's sequence control, see section 26.3.10.1, Master Mode Operation.

26.2.8 RSPI Bit Rate Register (SPBR)

Address: 0008 838Ah

	b7	b6	b5	b4	b3	b2	b1	b0
	SPR7	SPR6	SPR5	SPR4	SPR3	SPR2	SPR1	SPR0
Value after reset:	1	1	1	1	1	1	1	1

SPBR which can be read from or written to by the CPU sets the bit rate in master mode. If the contents of SPBR are changed by the CPU while both the SPCR.MSTR and SPE bits are 1 with the RSPI function in master mode enabled, subsequent operations cannot be guaranteed.

When the RSPI is used in slave mode, the bit rate depends on the bit rate of the input clock (bit rate satisfying the electrical characteristics should be used) regardless of the settings of SPBR and the SPCMDm.BRDV[1:0] bits (bit rate division setting bits).
The bit rate is determined by combinations of the SPBR setting and the BRDV[1:0] bit setting in SPCMD0 to SPCMD7. The equation for calculating the bit rate is given below. In the equation, n denotes an SPBR setting (0, 1, 2, …, 255), and N denotes a BRDV[1:0] bit setting (0, 1, 2, 3).

$$\text{Bit rate} = \frac{f(\text{PCLK})}{2 \times (n+1)\ 2^{N}}$$

Table 26.4 shows examples of the relationship between the SPBR register and BRDV[1:0] bit settings.

Table 26.4 Relationship between SPBR and BRDV[1:0] Bit Settings

SPBR (n)	BRDV[1:0] Bits (N)	Division Ratio	Bit Rate			
			PCLK = 32 MHz	PCLK = 36 MHz	PCLK = 40 MHz	PCLK = 50 MHz
0	0	2	16.0 Mbps*1	18.0 Mbps*1	20.0 Mbps*1	25.0 Mbps*1
1	0	4	8.00 Mbps	9.00 Mbps	10.0 Mbps	12.5 Mbps
2	0	6	5.33 Mbps	6.00 Mbps	6.67 Mbps	8.33 Mbps
3	0	8	4.00 Mbps	4.50 Mbps	5.00 Mbps	6.25 Mbps
4	0	10	3.20 Mbps	3.60 Mbps	4.00 Mbps	5.00 Mbps
5	0	12	2.67 Mbps	3.00 Mbps	3.33 Mbps	4.16 Mbps
5	1	24	1.33 Mbps	1.50 Mbps	1.67 Mbps	2.08 Mbps
5	2	48	667 kbps	750 kbps	833 kbps	1.04 Mbps
5	3	96	333 kbps	375 kbps	417 kbps	521 kbps
255	3	4096	7.81 kbps	8.80 kbps	9.78 kbps	12.2 kbps

Note 1. Can be set in this LSI but bit rates satisfying the electrical characteristics should be used.

26.2.9 RSPI Data Control Register (SPDCR)

Address: 0008 838Bh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	SPLW	SPRDTD	SLSEL[1:0]		SPFC[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1, b0	SPFC[1:0]	Number of Frames Specification	These bits specify the number of frames that can be stored in SPDR. Table 26.5 and Figure 26.2 show the frame configurations that can be stored in SPDR and examples of combinations of settings for transmission and reception. If combinations of settings other than those shown in the examples are made, subsequent operations cannot be guaranteed.	R/W
b3, b2	SLSEL[1:0]	SSI Pin Output Selection	See table below.	R/W
b4	SPRDTD	RSPI Receive/Transmit Data Selection	0: SPDR values are read from the receive buffer 1: SPDR values are read from the transmit buffer (but only if the transmit buffer is empty)	R/W
b5	SPLW	RSPI Longword Access/ Word Access Specification	0: SPDR is accessed in words 1: SPDR is accessed in longwords	R/W
b7, b6	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

	SLSEL [1:0] = 00	SLSEL [1:0] = 01	SLSEL [1:0] = 10	SLSEL [1:0] = 11
SSL3	Output	I/O	I/O	Setting prohibited
SSL2	Output	I/O	I/O	
SSL1	Output	I/O	Output	
SSL0	Output	Output	Output	

Operation is not guaranteed if SLSEL[1:0] = 11 is set.

SPDCR is a register used to set the number of frames that can be stored in SPDR, control the SSL pin output and reading from SPDR, and select the width (longword or word) for access to SPDR.
Up to four frames can be transmitted or received in one round of transmission or reception activation. The amount of data in each transfer is controlled by the combination of the RSPI data length specification bits (SPB[3:0]) in the RSPI command register (SPCMDm, m = 0 to 7), the RSPI sequence length specification bits (SPSLN[2:0]) in the RSPI sequence control register (SPSCR), and the number of frames specification bits (SPFC[1:0]) in the RSPI data control register (SPDCR).
When changing the SPDCR.SPFC[1:0] bits while the SPCR.SPE bit is 1 with the RSPI function enabled, the bits should be changed while the SPSR.IDLNF flag is 0.

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SPFC[1:0] Bits (Number of Frames Specification)

The SPFC[1:0] bits specify the number of frames that can be stored in SPDR. Up to four frames can be transmitted or received in one round of transmission or reception, and the amount of data is determined by the combination of the RSPI data length specification bits (SPB[3:0]) in the RSPI command register (SPCMDm), the RSPI sequence length specification bits (SPSLN[2:0]) in the RSPI sequence control register (SPSCR), and the number of frames specification bits (SPFC[1:0]) in the RSPI data control register (SPDCR). Also, the SPFC[1:0] bits specify the number of received data at which the RSPI receive buffer full interrupt is requested. Table 26.5 and Figure 26.2 show the frame

configurations that can be stored in SPDR and examples of combinations of settings for transmission and reception. If combinations of settings other than those shown in the examples are made, subsequent operations are not guaranteed.

SLSEL[1:0] Bits (SSl Pin Output Selection)

The SLSEL[1:0] bits control the SSL pin output in master mode.

SPRDTD Bit (RSPI Receive/Transmit Data Selection)

The SPRDTD bit selects whether the RSPI data register (SPDR) reads values from the receive buffer or from the transmit buffer.

If reading is from the transmit buffer, the value written to SPDR immediately beforehand is read.

SPLW Bit (RSPI Longword Access/Word Access Specification)

The SPLW bit specifies the access width for SPDR. Access to SPDR is in words when the SPLW bit is 0 and in longwords when the SPLW bit is 1.

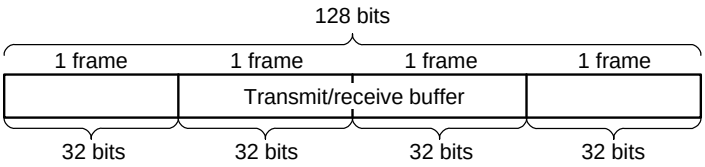
Also, when the SPLW bit is 0, set the SPCMD.SPB[3:0] bits (RSPI data length specification bits) to 8 to 16 bits. When 20, 24, or 32 bits is specified, operation is not guaranteed.

Table 26.5 Data Length Settable by SPB[3:0] Bits

Setting	SPB[3:0]	SPSLN[2:0]	SPFC[1:0]	Number of Frames for Transfer	Number of Frames at which Receive Buffer Full Interrupt Occurs or Transmit Buffer Holding Data is Recognized
1-1	N	000	00	1	1
1-2	N	000	01	2	2
1-3	N	000	10	3	3
1-4	N	000	11	4	4
2-1	N, M	001	01	2	2
2-2	N, M	001	11	4	4
3	N, M, O	010	10	3	3
4	N, M, O, P	011	11	4	4
5	N, M, O, P, Q	100	00	5	1
6	N, M, O, P, Q, R	101	00	6	1
7	N, M, O, P, Q, R, S	110	00	7	1
8	N, M, O, P, Q, R, S, T	111	00	8	1

N, M, O, P, Q, R, S, T: Data length that can be specified by the SPB[3:0] bits

• Frame configuration



Examples of combination of settings for transmission and reception
With one activation, data can be transmitted or received as shown below when settings 1-1 to 8 in table 25.5 are made.

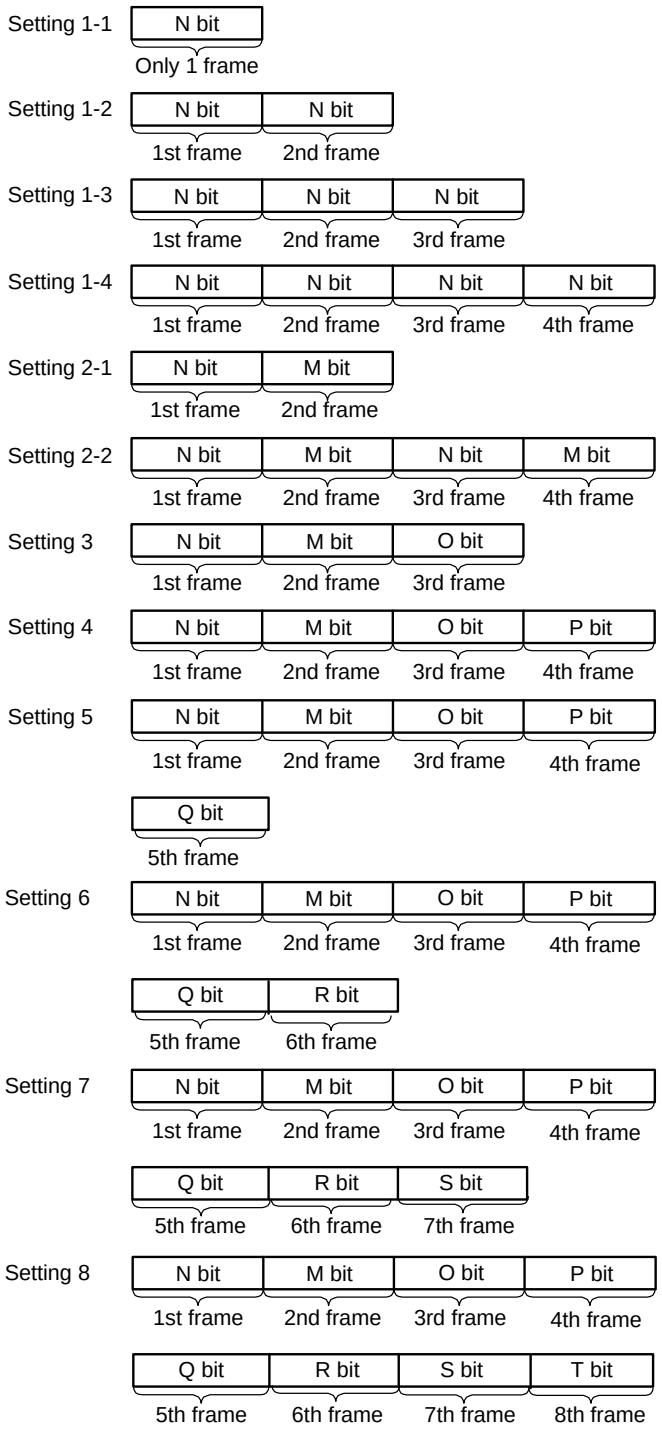


Figure 26.2 Frame Configurations and Examples of Combinations of Transmission and Reception Settings

26.2.10 RSPI Clock Delay Register (SPCKD)

Address: 0008 838Ch

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	SCKDL[2:0]		
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b2 to b0	SCKDL[2:0]	RSPCK Delay Setting	b2 b1 b0 0 0 0: 1 RSPCK 0 0 1: 2 RSPCK 0 1 0: 3 RSPCK 0 1 1: 4 RSPCK 1 0 0: 5 RSPCK 1 0 1: 6 RSPCK 1 1 0: 7 RSPCK 1 1 1: 8 RSPCK	R/W
b7 to b3	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

SPCKD sets a period from the beginning of SSL signal assertion to RSPCK oscillation (RSPCK delay) when the SPCMD.SCKDEN bit is 1. If the contents of SPCKD are changed while both the SPCR.MSTR and SPCR.SPE bits are 1 with the RSPI function in master mode enabled, subsequent operations cannot be guaranteed.
When using the RSPI in slave mode, set the SCKDL[2:0] bits to 000.

SCKDL[2:0] Bits (RSPCK Delay Setting)

The SCKDL[2:0] bits set an RSPCK delay value when the SPCMD.SCKDEN bit is 1.
When using the RSPI in slave mode, set the SCKDL[2:0] bits to 000.

26.2.11 RSPI Slave Select Negation Delay Register (SSLND)

Address: 0008 838Dh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	SLNDL[2:0]		
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b2 to b0	SLNDL[2:0]	SSL Negation Delay Setting	b2 b1 b0 0 0 0: 1 RSPCK 0 0 1: 2 RSPCK 0 1 0: 3 RSPCK 0 1 1: 4 RSPCK 1 0 0: 5 RSPCK 1 0 1: 6 RSPCK 1 1 0: 7 RSPCK 1 1 1: 8 RSPCK	R/W
b7 to b3	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

SSLND sets a period (SSL negation delay) from the transmission of a final RSPCK edge to the negation of the SSL signal during a serial transfer by the RSPI in master mode. If the contents of SSLND are changed while both the SPCR.MSTR and SPCR.SPE bits are 1 with the RSPI function in master mode enabled, subsequent operations cannot be guaranteed.
When using the RSPI in slave mode, set the SLNDL[2:0] bits to 000.

SLNDL[2:0] Bits (SSL Negation Delay Setting)

The SLNDL[2:0] bits set an SSL negation delay value when the RSPI is in master mode.
When using the RSPI in slave mode, set the SLNDL[2:0] bits to 000.

26.2.12 RSPI Next-Access Delay Register (SPND)

Address: 0008 838Eh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	SPNDL[2:0]		
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b2 to b0	SPNDL[2:0]	RSPI Next-Access Delay Setting	b2 b1 b0 0 0 0: 1 RSPCK + 2 PCLK 0 0 1: 2 RSPCK + 2 PCLK 0 1 0: 3 RSPCK + 2 PCLK 0 1 1: 4 RSPCK + 2 PCLK 1 0 0: 5 RSPCK + 2 PCLK 1 0 1: 6 RSPCK + 2 PCLK 1 1 0: 7 RSPCK + 2 PCLK 1 1 1: 8 RSPCK + 2 PCLK	R/W
b7 to b3	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

SPND sets a non-active period (next-access delay) after termination of a serial transfer when the SPCMD.SPNDEN bit is 1. If the contents of SPND are changed while both the SPCR.MSTR and SPCR.SPE bits are 1 with the RSPI function in master mode enabled, subsequent operations cannot be guaranteed.
When using the RSPI in slave mode, set the SPNDL[2:0] bits to 000.

SPNDL[2:0] Bits (RSPI Next-Access Delay Setting)

The SPNDL[2:0] bits set a next-access delay when the SPCMD.SPNDEN bit is 1.
When using the RSPI in slave mode, set the SPNDL[2:0] bits to 000.

26.2.13 RSPI Control Register 2 (SPCR2)

Address: 0008 838Fh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	PTE	SPIIE	SPOE	SPPE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	SPPE	Parity Enable	0: Does not add the parity bit to transmit data and does not check the parity bit of receive data 1: Adds the parity bit to transmit data and checks the parity bit of receive data (when SPCR.TXMD = 0) Adds the parity bit to transmit data but does not check the parity bit of receive data (when SPCR.TXMD = 1)	R/W
b1	SPOE	Parity Mode	0: Selects even parity for use in transmission and reception 1: Selects odd parity for use in transmission and reception	R/W
b2	SPIIE	RSPI Idle Interrupt Enable	0: Disables the generation of idle interrupt requests 1: Enables the generation of idle interrupt requests	R/W
b3	PTE	Parity Self-Testing	0: Disables the self-diagnosis function of the parity circuit 1: Enables the self-diagnosis function of the parity circuit	R/W
b7 to b4	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

SPCR2 sets the operating mode of the RSPI. If the SPPE bit or SPOE bit in SPCR2 is changed while the SPCR.SPE bit is 1 with the RSPI function enabled, subsequent operations cannot be guaranteed.

SPPE Bit (Parity Enable)

The SPPE bit enables or disables the parity function.
The parity bit is added to transmit data and parity checking is performed for receive data when the communications operating mode select bit (TXMD) in the RSPI control register (SPCR) is 0 and the SPPE bit in SPCR is 1.
The parity bit is added to transmit data but parity checking is not performed for receive data when the SPCR.TXMD bit is 1 and the SPPE bit in SPCR is 1.

SPOE Bit (Parity Mode)

When even parity is set, parity bit addition is performed so that the total number of 1-bits in the transmit/receive character plus the parity bit is even. Similarly, when odd parity is set, parity bit addition is performed so that the total number of 1-bits in the transmit/receive character plus the parity bit is odd.
The SPOE bit is valid only when the SPPE bit is 1.

SPIIE Bit (RSPI Idle Interrupt Enable)

The SPIIE bit enables or disables the generation of RSPI idle interrupt requests when the RSPI being in the idle state is detected and the IDLNF flag in the RSPI status register (SPSR) is cleared to 0.

PTE Bit (Parity Self-Testing)

The PTE bit enables the self-diagnosis function of the parity circuit in order to check whether the parity function is operating correctly.

26.2.14 RSPI Command Register m (SPCMDm, m = 0 to 7)

Address: SPCMD0 0008 8390h, SPCMD1 0008 8392h, SPCMD2 0008 8394h, SPCMD3 0008 8396h, SPCMD4 0008 8398h, SPCMD5 0008 839Ah, SPCMD6 0008 839Ch, SPCMD7 0008 839Eh

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	SCKDEN	SLNDEN	SPNDEN	LSBF	SPB[3:0]				SSLKP	SSLA[2:0]			BRDV[1:0]		CPOL	CPHA
Value after reset:	0	0	0	0	0	1	1	1	0	0	0	0	1	1	0	1

Bit	Symbol	Bit Name	Description	R/W
b0	CPHA	RSPCK Phase Setting	0: Data sampling on odd edge, data variation on even edge 1: Data variation on odd edge, data sampling on even edge	R/W
b1	CPOL	RSPCK Polarity Setting	0: RSPCK = 0 when idle 1: RSPCK = 1 when idle	R/W
b3, b2	BRDV[1:0]	Bit Rate Division Setting	b3 b2 0 0: These bits select the base bit rate 0 1: These bits select the base bit rate divided by 2 1 0: These bits select the base bit rate divided by 4 1 1: These bits select the base bit rate divided by 8	R/W
b6 to b4	SSLA[2:0]	SSL Signal Assertion Setting	b6 b5 b4 0 0 0: SSL0 0 0 1: SSL1 0 1 0: SSL2 0 1 1: SSL3 1 x x: — (Setting prohibited) x: Don't care	R/W
b7	SSLKP	SSL Signal Level Keeping	0:Negates all SSL signals upon completion of transfer 1:Keeps the SSL signal level from the end of transfer until the beginning of the next access.	R/W
b11 to b8	SPB[3:0]	RSPI Data Length Setting	b11 b10 b9 b8 0100 to 0111: 8 bits 1 0 0 0: 9 bits 1 0 0 1: 10 bits 1 0 1 0: 11 bits 1 0 1 1: 12 bits 1 1 0 0: 13 bits 1 1 0 1: 14 bits 1 1 1 0: 15 bits 1 1 1 1: 16 bits 0 0 0 0: 20 bits 0 0 0 1: 24 bits 0010, 0011: 32 bits	R/W
b12	LSBF	RSPI LSB First	0: MSB first 1: LSB first	R/W
b13	SPNDEN	RSPI Next-Access Delay Setting Enable	0:A next-access delay of 1 RSPCK + 2 PCLK 1:A next-access delay is equal to the setting of the RSPI next-access delay register (SPND)	R/W
b14	SLNDEN	SSL Negation Delay Setting Enable	0:An SSL negation delay of 1 RSPCK 1:An SSL negation delay is equal to the setting of the RSPI slave select negation delay register (SSLND)	R/W
b15	SCKDEN	RSPCK Delay Setting Enable	0:An RSPCK delay of 1 RSPCK 1:An RSPCK delay is equal to the setting of the RSPI clock delay register (SPCKD)	R/W

SPCMDm is used to set a transfer format for the RSPI in master mode. Some of the bits in SPCMD0 are used to set a transfer mode for the RSPI in slave mode. The RSPI in master mode sequentially references SPCMDm according to the settings in the SPSLN[2:0] bits in the RSPI sequence control register (SPSCR), and executes the serial transfer that is set

in the referenced SPCMDm.
SPCMDm should be set while the transmit buffer is empty (data for the next transfer is not set) and before setting of the data that is to be transmitted when that SPCMDm is referenced.
SPCMDm that is referenced by the RSPI in master mode can be checked by means of the SPCP[2:0] bits in the RSPI sequence status register (SPSSR). If the contents of SPCMDm are changed with the RSPI function in slave mode enabled, subsequent operations cannot be guaranteed.

CPHA Bit (RSPCK Phase Setting)

The CPHA bit sets an RSPCK phase of the RSPI in master mode or slave mode. Data communications between RSPI modules require the same RSPCK phase setting between the modules.

CPOL Bit (RSPCK Polarity Setting)

The CPOL bit sets an RSPCK polarity of the RSPI in master mode or slave mode. Data communications between RSPI modules require the same RSPCK polarity setting between the modules.

BRDV[1:0] Bits (Bit Rate Division Setting)

The BRDV[1:0] bits are used to determine the bit rate. A bit rate is determined by combinations of the settings in the BRDV[1:0] bits and SPBR (see section 26.2.8, RSPI Bit Rate Register (SPBR)). The settings in SPBR determine the base bit rate. The settings in the BRDV[1:0] bits are used to select a bit rate which is obtained by dividing the base bit rate by 1, 2, 4, or 8. In SPCMDm, different BRDV[1:0] bit settings can be specified. This permits the execution of serial transfers at a different bit rate for each command.

SSLA[2:0] Bits (SSL Signal Assertion Setting)

The SSLA[2:0] bits control the SSL signal assertion when the RSPI performs serial transfers in master mode. Setting the SSLA[2:0] bits controls the assertion for the SSLi (i = 0 o 3) signals. When an SSL signal is asserted, its polarity is determined by the set value in the corresponding SSLP. When the SSLA[2:0] bits are set to 000 in multi-master mode, serial transfers are performed with all the SSLi signals in the negated state (as the SSL0 pin acts as input).
When using the RSPI in slave mode, set the SSLA[2:0] bits to 000.

SSLKP Bit (SSL Signal Level Keeping)

When the RSPI in master mode performs a serial transfer, the SSLKP bit specifies whether the SSL signal level for the current command is to be kept or negated between the SSL negation timing associated with the current command and the SSL assertion timing associated with the next command.
When using the RSPI in slave mode, the SSLKP bit should be set to 0.

SPB[3:0] Bits (RSPI Data Length Setting)

The SPB[3:0] bits set a transfer data length for the RSPI in master mode or slave mode.

LSBF Bit (RSPI LSB First)

The LSBF bit sets the data format of the RSPI in master mode or slave mode to MSB first or LSB first.

SPNDEN Bit (RSPI Next-Access Delay Setting Enable)

The SPNDEN bit sets the period from the time the RSPI in master mode terminates a serial transfer and sets the SSL signal inactive until the RSPI enables the SSL signal assertion for the next access (next-access delay). If the SPNDEN bit is 0, the RSPI sets the next-access delay to 1 RSPCK + 2 PCLK. If the SPNDEN bit is 1, the RSPI inserts a next-access delay in compliance with the SPND setting.
When using the RSPI in slave mode, the SPNDEN bit should be set to 0.

SLNDEN Bit (SSL Negation Delay Setting Enable)

The SLNDEN bit sets the period (SSL negation delay) from the time the master mode RSPI stops RSPCK oscillation until the RSPI sets the SSL signal inactive. If the SLNDEN bit is 0, the RSPI sets the SSL negation delay to 1 RSPCK. If the SLNDEN bit is 1, the RSPI negates the SSL signal at an SSL negation delay in compliance with the SSLND setting. When using the RSPI in slave mode, the SLNDEN bit should be set to 0.

SCKDEN Bit (RSPCK Delay Setting Enable)

The SCKDEN bit sets the period from the point when the RSPI in master mode activates the SSL signal until the RSPCK starts oscillation (RSPI clock delay). If the SCKDEN bit is 0, the RSPI sets the RSPCK delay to 1 RSPCK. If the SCKDEN bit is 1, the RSPI starts the oscillation of RSPCK at an RSPCK delay in compliance with the SPCKD setting. When using the RSPI in slave mode, the SCKDEN bit should be set to 0.

26.3 Operation

In this section, the serial transfer period means a period from the beginning of driving valid data to the fetching of the final valid data.

26.3.1 Overview of RSPI Operations

The RSPI is capable of synchronous serial transfers in slave mode (SPI operation), single-master mode (SPI operation), multi-master mode (SPI operation), slave mode (clock synchronous operation), and master mode (clock synchronous operation). A particular mode of the RSPI can be selected by using the MSTR, MODFEN, and SPMS bits in SPCR. Table 26.6 gives the relationship between RSPI modes and SPCR settings, and a description of each mode.

Table 26.6 Relationship between RSPI Modes and SPCR and Description of Each Mode

Mode	Slave (SPI Operation)	Single-Master (SPI Operation)	Multi-Master (SPI Operation)	Slave (Clock Synchronous Operation)	Master (Clock Synchronous Operation)
MSTR bit setting	0	1	1	0	1
MODFEN bit setting	0 or 1	0	1	0	0
SPMS bit setting	0	0	0	1	1
RSPCK signal	Input	Output	Output/Hi-Z	Input	Output
MOSI signal	Input	Output	Output/Hi-Z	Input	Output
MISO signal	Output/Hi-Z	Input	Input	Output	Input
SSL0 signal	Input	Output	Input	Hi-Z	Hi-Z
SSL1 to SSL3 signals	Hi-Z	Output/Hi-Z	Output/Hi-Z	Hi-Z	Hi-Z
SSL polarity modification function	Supported	Supported	Supported	—	—
Transfer rate	Up to PCLK/8	Up to PCLK/2	Up to PCLK/2	Up to PCLK/8	Up to PCLK/2
Clock source	RSPCK input	On-chip baud rate generator	On-chip baud rate generator	RSPCK input	On-chip baud rate generator
Clock polarity	Two	Two	Two	Two	Two
Clock phase	Two	Two	Two	One (CPHA = 1)	Two
First transfer bit	MSB/LSB	MSB/LSB	MSB/LSB	MSB/LSB	MSB/LSB
Transfer data length	8 to 32 bits	8 to 32 bits	8 to 32 bits	8 to 32 bits	8 to 32 bits
Burst transfer	Possible (CPHA = 1)	Possible (CPHA = 0, 1)	Possible (CPHA = 0, 1)	—	—
RSPCK delay control	Not supported	Supported	Supported	Not supported	Supported
SSL negation delay control	Not supported	Supported	Supported	Not supported	Supported
Next-access delay control	Not supported	Supported	Supported	Not supported	Supported
Transfer activation method	SSL input active or RSPCK oscillation	Transmit buffer is written to at generation of a transmit buffer empty interrupt request	Transmit buffer is written to at generation of a transmit buffer empty interrupt request	RSPCK oscillation	Transmit buffer is written to at generation of a transmit buffer empty interrupt request
Sequence control	Not supported	Supported	Supported	Not supported	Supported
Transmit buffer empty detection	Supported	Supported	Supported	Supported	Supported
Receive buffer full detection	Supported*1	Supported*1	Supported*1	Supported*1	Supported*1
Overrun error detection	Supported*1	Supported*1	Supported*1	Supported*1	Supported*1
Parity error detection	Supported*1*2	Supported*1*2	Supported*1*2	Supported*1*2	Supported*1*2
Mode fault error detection	Supported (MODFEN = 1)	Not supported	Supported	Not supported	Not supported

Note 1. When the SPCR.TXMD bit is 1, receiver buffer full detection, overrun error detection, and parity error detection are not performed.
Note 2. When the SPCR2.SPPE bit is 0, parity error detection is not performed.

26.3.2 Controlling RSPI Pins

According to the MSTR, MODFEN, and SPMS bits in SPCR, the RSPI can automatically switch pin directions and output modes. Table 26.7 shows the relationship between pin states and bit settings.

Table 26.7 Relationship between Pin States and Bit Settings

Mode	Pin	Pin State*1
Single-master mode (SPI operation) (MSTR = 1, MODFEN = 0, SPMS = 0)	RSPCK	Output
	SSL0 to SSL3	Output
	MOSI	Output
	MISO	Input
Multi-master mode (SPI operation) (MSTR = 1, MODFEN = 1, SPMS = 0)	RSPCK*2	Output/Hi-Z
	SSL0	Input
	SSL1 to SSL3*2	Output/Hi-Z
	MOSI*2	Output/Hi-Z
	MISO	Input
Slave mode (SPI operation) (MSTR = 0, SPMS = 0)	RSPCK	Input
	SSL0	Input
	SSL1 to SSL3	Hi-Z
	MOSI	Input
	MISO*3	Output/Hi-Z
Master mode (Clock synchronous operation) (MSTR = 1, MODFEN = 0, SPMS = 1)	RSPCK	Output
	SSL0 to SSL3*4	Hi-Z
	MOSI	Output
	MISO	Input
Slave mode (Clock synchronous operation) (MSTR = 0, SPMS = 1)	RSPCK	Input
	SSL0 to SSL3*4	Hi-Z
	MOSI	Input
	MISO	Output

Note 1. RSPI settings are not indicated in the multiplex pins for which the RSPI function is not selected.
Note 2. When SSL0 is at the active level, the pin state is Hi-Z.
Note 3. When SSL0 is at the non-active level or the SPE bit in SPCR is cleared (= 0), the pin state is Hi-Z.
Note 4. In clock synchronous operation, SSL0 to SSL3 are available for use as I/O port pins.

The RSPI in single-master mode (SPI operation) or multi-master mode (SPI operation) determines MOSI signal values during the SSL negation period (including the SSL retention period during a burst transfer) according to MOIFE and MOIFV bit settings in SPPCR, as shown in Table 26.8.

Table 26.8 MOSI Signal Value Determination during SSL Negation Period

SPPCR.MOIFE Bit	SPPCR.MOIFV Bit	MOSI Signal Value during SSL Negation Period
0	0, 1	Final data from previous transfer
1	0	Always 0
1	1	Always 1

26.3.3 RSPI System Configuration Examples

26.3.3.1 Single Master/Single Slave (with This LSI Acting as Master)

Figure 26.3 shows a single-master/single-slave RSPI system configuration example when this LSI is used as a master. In the single-master/single-slave configuration, the SSL0 to SSL3 output of this LSI (master) are not used. The SSL input of the RSPI slave is fixed to the low level, and the RSPI slave is always maintained in a select state.*1
This LSI (master) always drives the RSPCK and MOSI. The RSPI slave always drives the MISO.

Note 1. In the transfer format corresponding to the case where the SPCMDm.CPHA bit (m = 0 to 7) is 0, there are slave devices for which the SSL signal cannot be fixed to the active level. In situations where the SSL signal cannot be fixed, the SSL output of this LSI should be connected to the SSL input of the slave device.

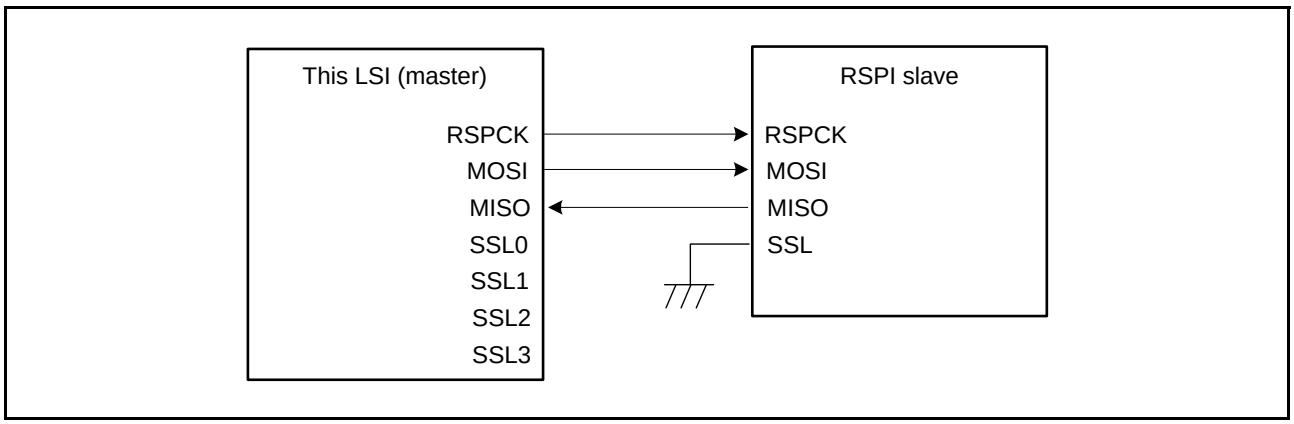


Figure 26.3 Single-Master/Single-Slave Configuration Example (This LSI = Master)

26.3.3.2 Single Master/Single Slave (with This LSI Acting as Slave)

Figure 26.4 shows a single-maFster/single-slave RSPI system configuration example when this LSI is used as a slave. When this LSI is to operate as a slave, the SSL0 pin is used as SSL input. The RSPI master always drives the RSPCK and MOSI. This LSI (slave) always drives the MISO.*1

In the single-slave configuration in which the SPCMD0.CPHA bit is set to 1, the SSL0 input of this LSI (slave) is fixed to the 0 level, this LSI (slave) is always maintained in a selected state, and in this manner it is possible to execute serial transfer (Figure 26.5).

Note 1. When SSL0 is at the active level, the pin state is Hi-Z.

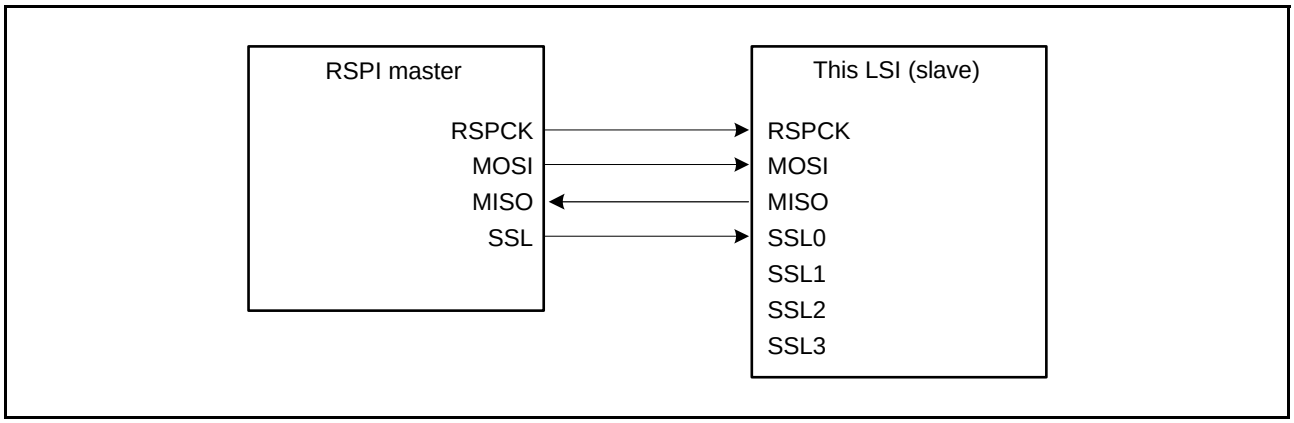


Figure 26.4 Single-Master/Single-Slave Configuration Example (This LSI = Slave)

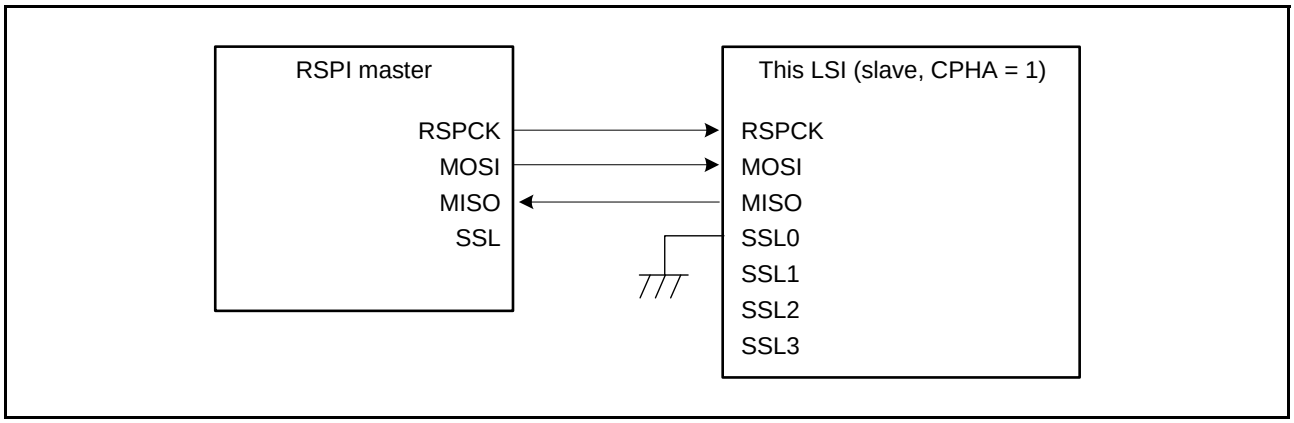


Figure 26.5 Single-Master/Single-Slave Configuration Example (This LSI = Slave, SPCMD0.CPHA = 1)

26.3.3.3 Single Master/Multi-Slave (with This LSI Acting as Master)

Figure 26.6 shows a single-master/multi-slave RSPI system configuration example when this LSI is used as a master. In the example of Figure 26.6, the RSPI system is comprised of this LSI (master) and four slaves (RSPI slave 0 to RSPI slave 3).

The RSPCK and MOSI outputs of this LSI (master) are connected to the RSPCK and MOSI inputs of RSPI slave 0 to RSPI slave 3. The MISO outputs of RSPI slave 0 to RSPI slave 3 are all connected to the MISO input of this LSI (master). SSL0 to SSL3 outputs of this LSI (master) are connected to the SSL inputs of RSPI slave 0 to RSPI slave 3, respectively.

This LSI (master) always drives RSPCK, MOSI, and SSL0 to SSL3. Of the RSPI slave 0 to RSPI slave 3, the slave that receives low-level input into the SSL input drives MISO.

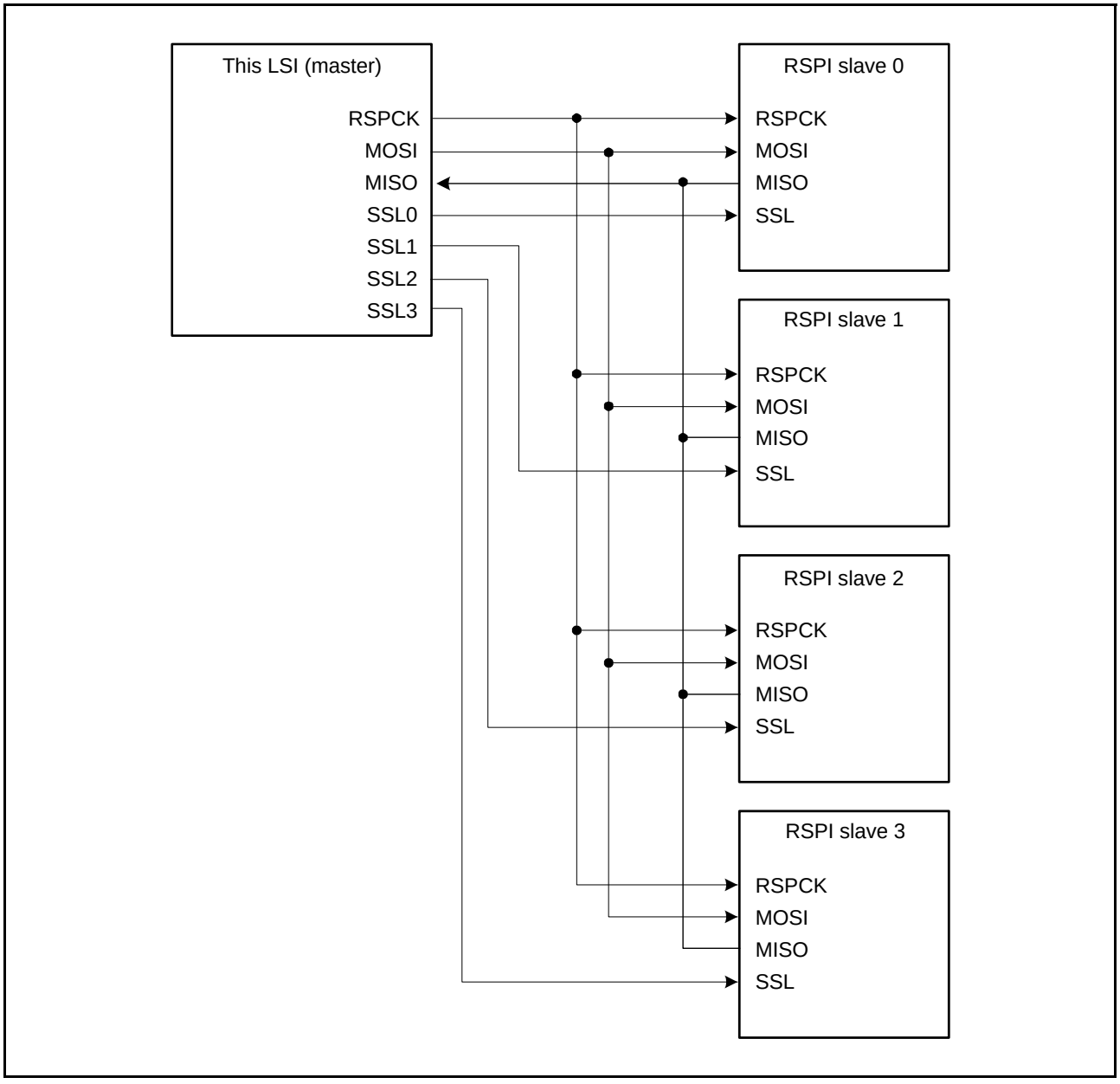


Figure 26.6 Single-Master/Multi-Slave Configuration Example (This LSI = Master)

26.3.3.4 Single Master/Multi-Slave (with This LSI Acting as Slave)

Figure 26.7 shows a single-master/multi-slave RSPI system configuration example when this LSI is used as a slave. In the example of Figure 26.7, the RSPI system is comprised of an RSPI master and two LSIs (slave X and slave Y). The RSPCK and MOSI outputs of the RSPI master are connected to the RSPCK and MOSI inputs of the LSIs (slave X and slave Y). The MISO outputs of the LSIs (slave X and slave Y) are all connected to the MISO input of the RSPI master. SSLX and SSLY outputs of the RSPI master are connected to the SSL0 inputs of the LSIs (slave X and slave Y), respectively.

The RSPI master always drives RSPCK, MOSI, SSLX, and SSLY. Of the LSIs (slave X and slave Y), the slave that receives low-level input into the SSL0 input drives MISO.

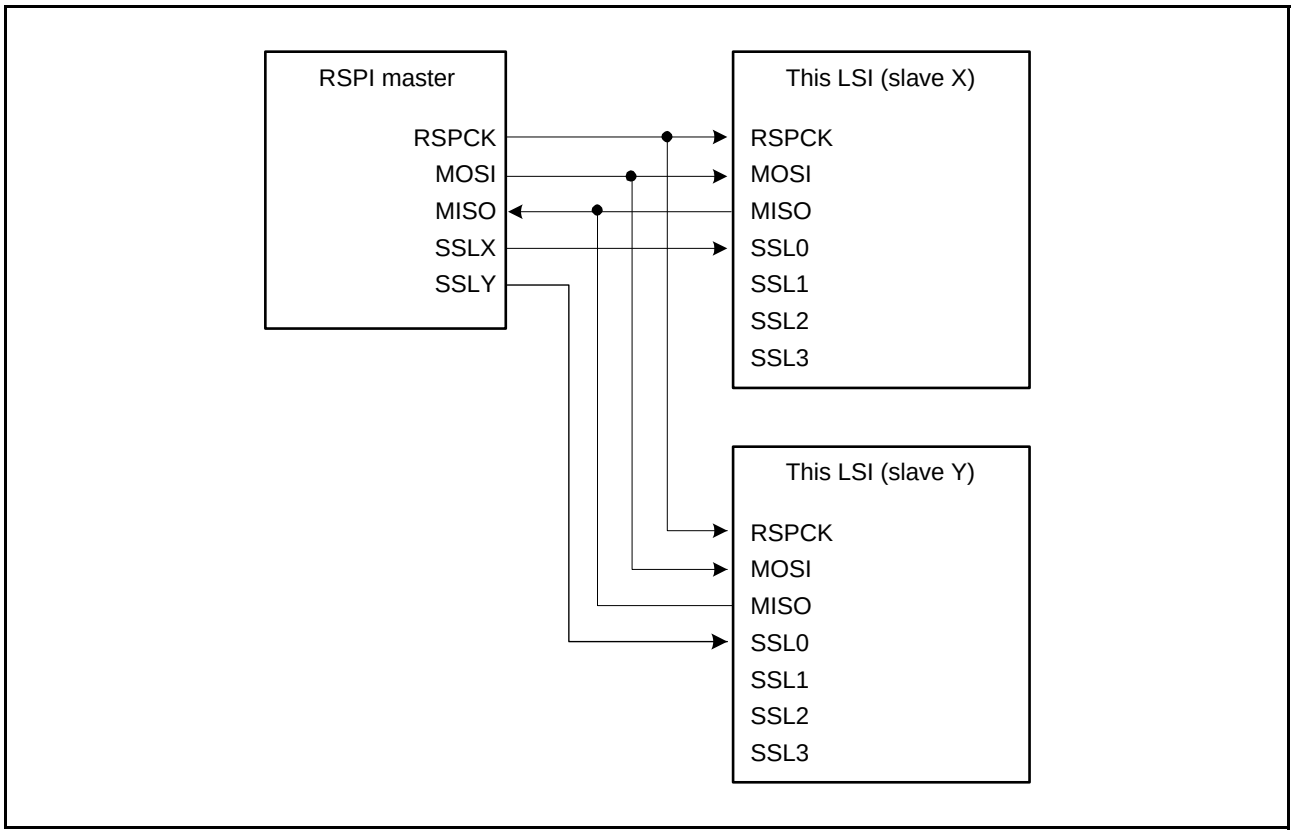


Figure 26.7 Single-Master/Multi-Slave Configuration Example (This LSI = Slave)

26.3.3.5 Multi-Master/Multi-Slave (with This LSI Acting as Master)

Figure 26.8 shows a multi-master/multi-slave RSPI system configuration example when this LSI is used as a master. In the example of Figure 26.8, the RSPI system is comprised of two LSIs (master X and master Y) and two RSPI slaves (RSPI slave 1 and RSPI slave 2).

The RSPCK and MOSI outputs of the LSIs (master X and master Y) are connected to the RSPCK and MOSI inputs of RSPI slaves 1 and 2. The MISO outputs of RSPI slaves 1 and 2 are connected to the MISO inputs of the LSIs (master X and master Y). Any generic port Y output from this LSI (master X) is connected to the SSL0 input of this LSI (master Y). Any generic port X output of this LSI (master Y) is connected to the SSL0 input of this LSI (master X). The SSL1 and SSL2 outputs of the LSIs (master X and master Y) are connected to the SSL inputs of the RSPI slaves 1 and 2. In this configuration example, because the system can be comprised solely of SSL0 input, and SSL1 and SSL2 outputs for slave connections, the SSL3 output of this LSI is not required.

This LSI drives RSPCK, MOSI, SSL1, and SSL2 when the SSL0 input level is 1. When the SSL0 input level is 0, this LSI detects a mode fault error, sets RSPCK, MOSI, SSL1, and SSL2 to Hi-Z, and releases the RSPI bus right to the other master. Of the RSPI slaves 1 and 2, the slave that receives low-level input into the SSL input drives MISO.

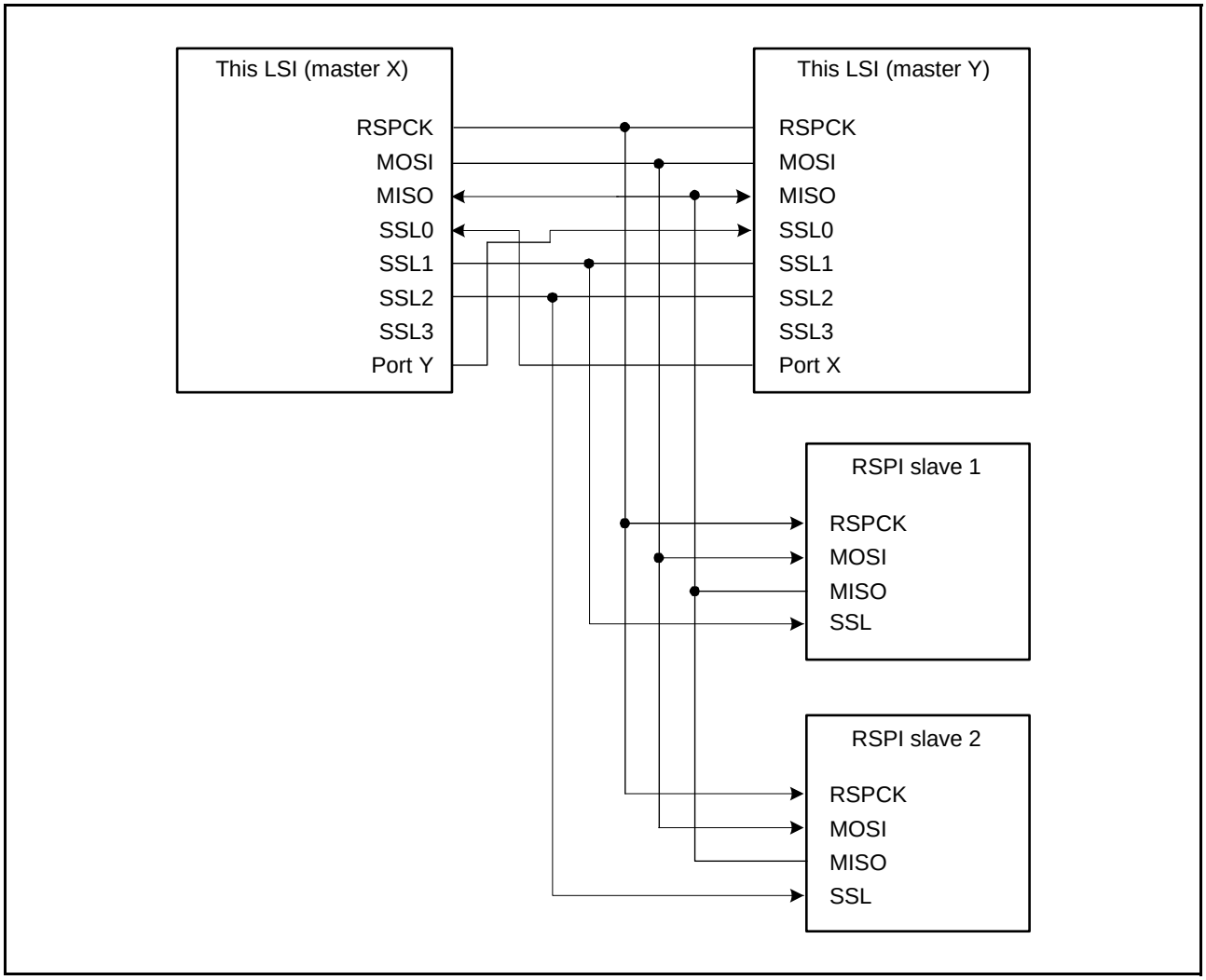


Figure 26.8 Multi-Master/Multi-Slave Configuration Example (This LSI = Master)

26.3.3.6 Master (Clock Synchronous Operation)/Slave (Clock Synchronous Operation) (with This LSI Acting as Master)

Figure 26.9 shows a master (clock synchronous operation)/slave (clock synchronous operation) RSPI system configuration example when this LSI is used as a master. In the master (clock synchronous operation)/slave (clock synchronous operation) configuration, SSL0 to SSL3 of this LSI (master) are not used.
This LSI (master) always drives the RSPCK and MOSI. The RSPI slave always drives the MISO.

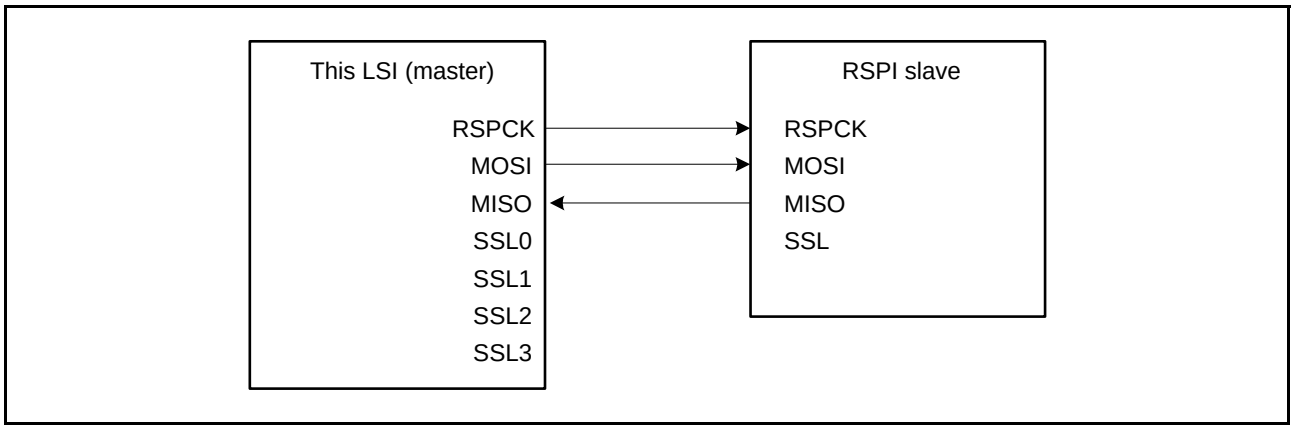


Figure 26.9 Master (Clock Synchronous Operation)/Slave (Clock Synchronous Operation) Configuration Example (This LSI = Master)

26.3.3.7 Master (Clock Synchronous Operation)/Slave (Clock Synchronous Operation) (with This LSI Acting as Slave)

Figure 26.10 shows a master (clock synchronous operation)/slave (clock synchronous operation) RSPI system configuration example when this LSI is used as a slave. When this LSI is to operate as a slave (clock synchronous operation), this LSI (slave) always drives the MISO and the RSPI master always drives the RSPCK and MOSI. In addition, SSL0 to SSL3 of this LSI (slave) are not used.
Only in the single-slave configuration in which the SPCMD0.CPHA bit is set to 1, this LSI (slave) can execute serial transfer.

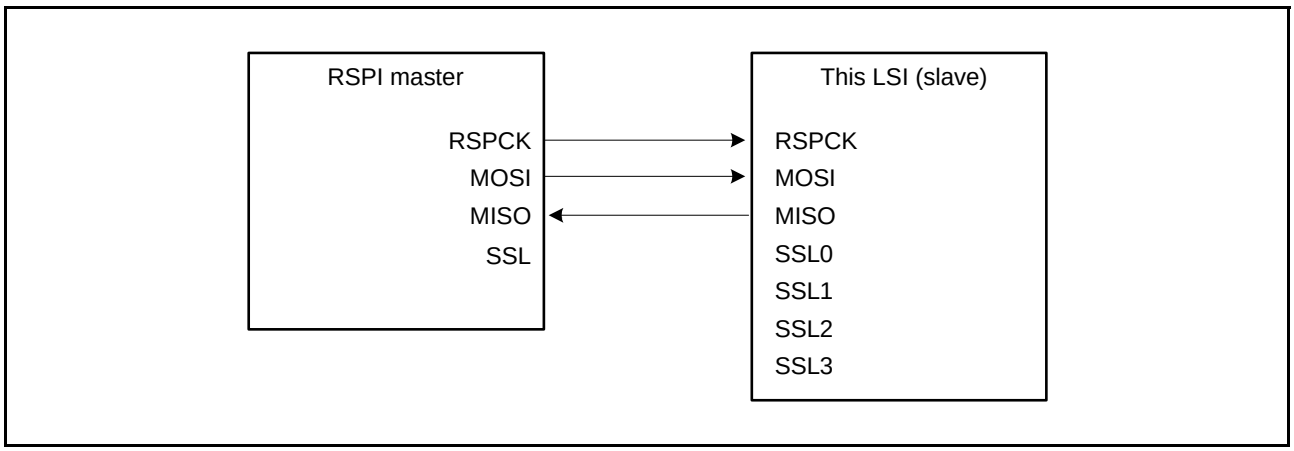


Figure 26.10 Master (Clock Synchronous Operation)/Slave (Clock Synchronous Operation) Configuration Example (This LSI = Slave, SPCMD0.CPHA = 1)

26.3.4 Transfer Format

26.3.4.1 CPHA = 0

Figure 26.11 shows a sample transfer format for the serial transfer of 8-bit data when the SPCMDm.CPHA bit is 0. Note that clock synchronous operation (the SPCR.SPMS bit is 1) is not guaranteed when the RSPI operates in slave mode (SPCR.MSTR = 0) and the CPHA bit is 0. In Figure 26.11, RSPCK (CPOL = 0) indicates the RSPCK signal waveform when the CPOL bit in SPCMDm is 0; RSPCK (CPOL = 1) indicates the RSPCK signal waveform when the CPOL bit is 1. The sampling timing represents the timing at which the RSPI fetches serial transfer data into the shift register. The input/output directions of the signals depend on the RSPI settings. For details, see section 26.3.2, Controlling RSPI Pins .

When the CPHA bit is 0, the driving of valid data to the MOSI and MISO signals commences at an SSL signal assertion timing. The first RSPCK signal change timing that occurs after the SSL signal assertion becomes the first transfer data fetch timing. After this timing, data is sampled at every 1 RSPCK cycle. The change timing for MOSI and MISO signals is always 1/2 RSPCK cycles after the transfer data fetch timing. The SPCMDm.CPOL bit setting does not affect the RSPCK signal operation timing; it only affects the signal polarity.

t1 denotes a period from an SSL signal assertion to RSPCK oscillation (RSPCK delay). t2 denotes a period from the termination of RSPCK oscillation to an SSL signal negation (SSL negation delay). t3 denotes a period in which SSL signal assertion is suppressed for the next transfer after the end of serial transfer (next-access delay). t1, t2, and t3 are controlled by a master device running on the RSPI system. For a description of t1, t2, and t3 when the RSPI of this LSI is in master mode, see section 26.3.10.1, Master Mode Operation.

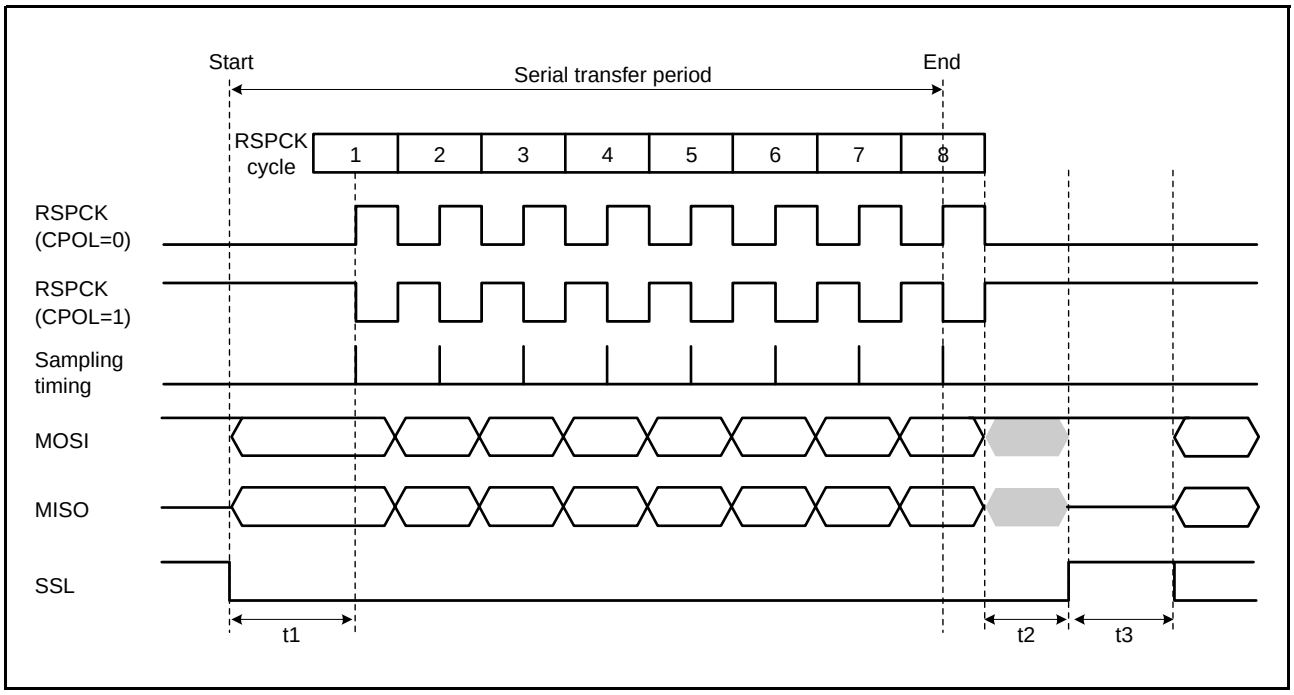


Figure 26.11 RSPI Transfer Format (CPHA = 0)

26.3.4.2 CPHA = 1 (m = 0 to 7)

Figure 26.12 shows a sample transfer format for the serial transfer of 8-bit data when the SPCMDm.CPHA bit is 1. However, when the SPCR.SPMS bit is 1, the SSL signals are not used, and only the three signals RSPCK, MOSI, and MISO handle communications. In Figure 26.12, RSPCK (CPOL = 0) indicates the RSPCK signal waveform when the CPOL bit in SPCMDm is 0; RSPCK (CPOL = 1) indicates the RSPCK signal waveform when the CPOL bit is 1. The sampling timing represents the timing at which the RSPI fetches serial transfer data into the shift register. The input/output directions of the signals depend on the RSPI mode (master or slave). For details, see section 26.3.2, Controlling RSPI Pins .

When the CPHA bit is 1, the driving of invalid data to the MISO signal commences at an SSL signal assertion timing. The output of valid data to the MOSI and MISO signals commences at the first RSPCK signal change timing that occurs after the SSL signal assertion. After this timing, data is updated at every 1 RSPCK cycle. The transfer data fetch timing is always 1/2 RSPCK cycles after the data update timing. The SPCMDm.CPOL bit setting does not affect the RSPCK signal operation timing; it only affects the signal polarity.

t1, t2, and t3 are the same as those in the case of SPCMDm.CPHA = 0. For a description of t1, t2, and t3 when the RSPI of this LSI is in master mode, see section 26.3.10.1, Master Mode Operation.

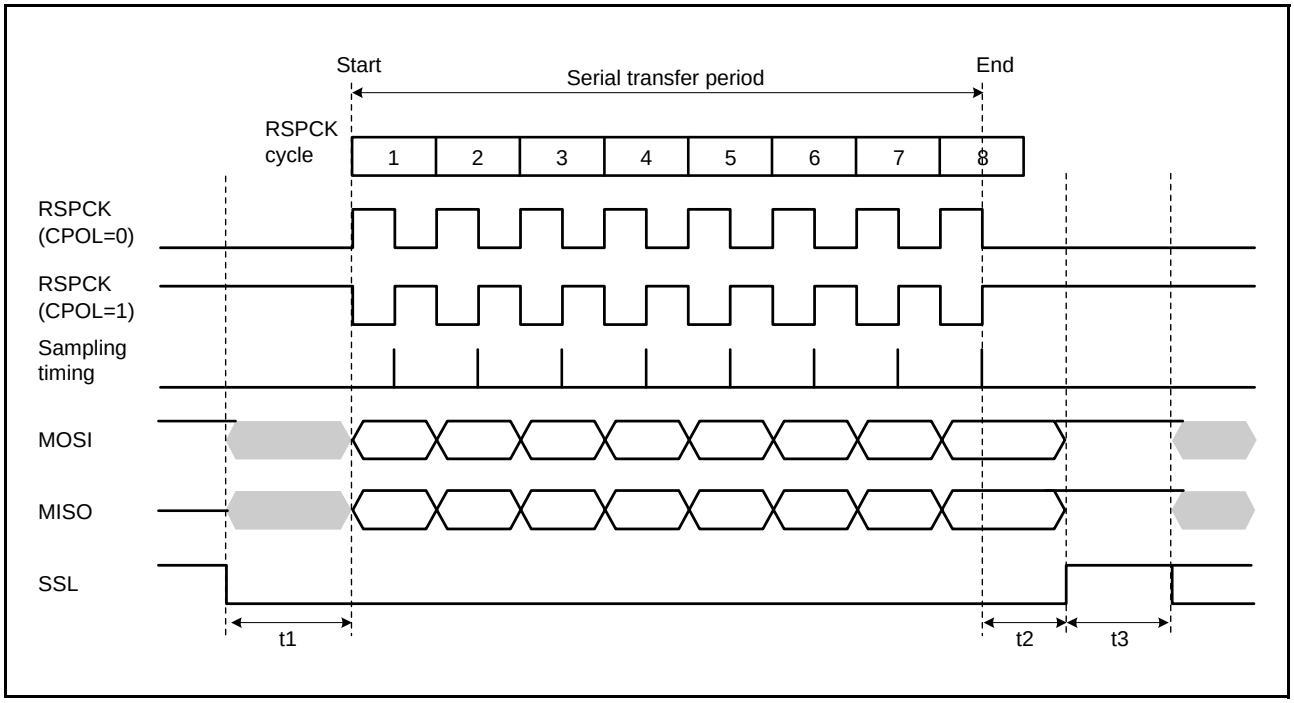


Figure 26.12 RSPI Transfer Format (CPHA = 1)

26.3.5 Data Format

The RSPI's data format depends on the settings in SPCMDm register (m = 0 to 7) and the SPCR2.SPPE bit. Irrespective of MSB/LSB first, the RSPI treats the range from the SPDR.LSB bit to the assigned data length as transfer data.

26.3.5.1 MSB First Transfer (32-Bit Data)

(1) Parity Function is Disabled (SPCR2.SPPE = 0)

Figure 26.13 shows the operation of SPDR and the shift register when the RSPI performs a 32-bit data length MSB-first data transfer with the parity function disabled.

Data T31 to T00 is written to the transmit buffer of SPDR. If the transmit buffer holds data and the shift register is empty, the RSPI copies the data in the transmit buffer of SPDR to the shift register, and fully populates the shift register. When serial transfer starts, the RSPI outputs data from the MSB (bit 31) of the shift register, and shifts in the data from the LSB (bit 0) of the shift register. When the RSPCK cycles required for the serial transfer of 32 bits have passed, data R31 to R00 is stored in the shift register. In this state, when performing full-duplex synchronous serial communications (SPCR.TXMD = 0), the RSPI copies the data from the shift register to the receive buffer of SPDR, and empties the shift register.

If another serial transfer is started before data is written to the transmit buffer of SPDR, received data R31 to R00 is shifted out from the shift register.

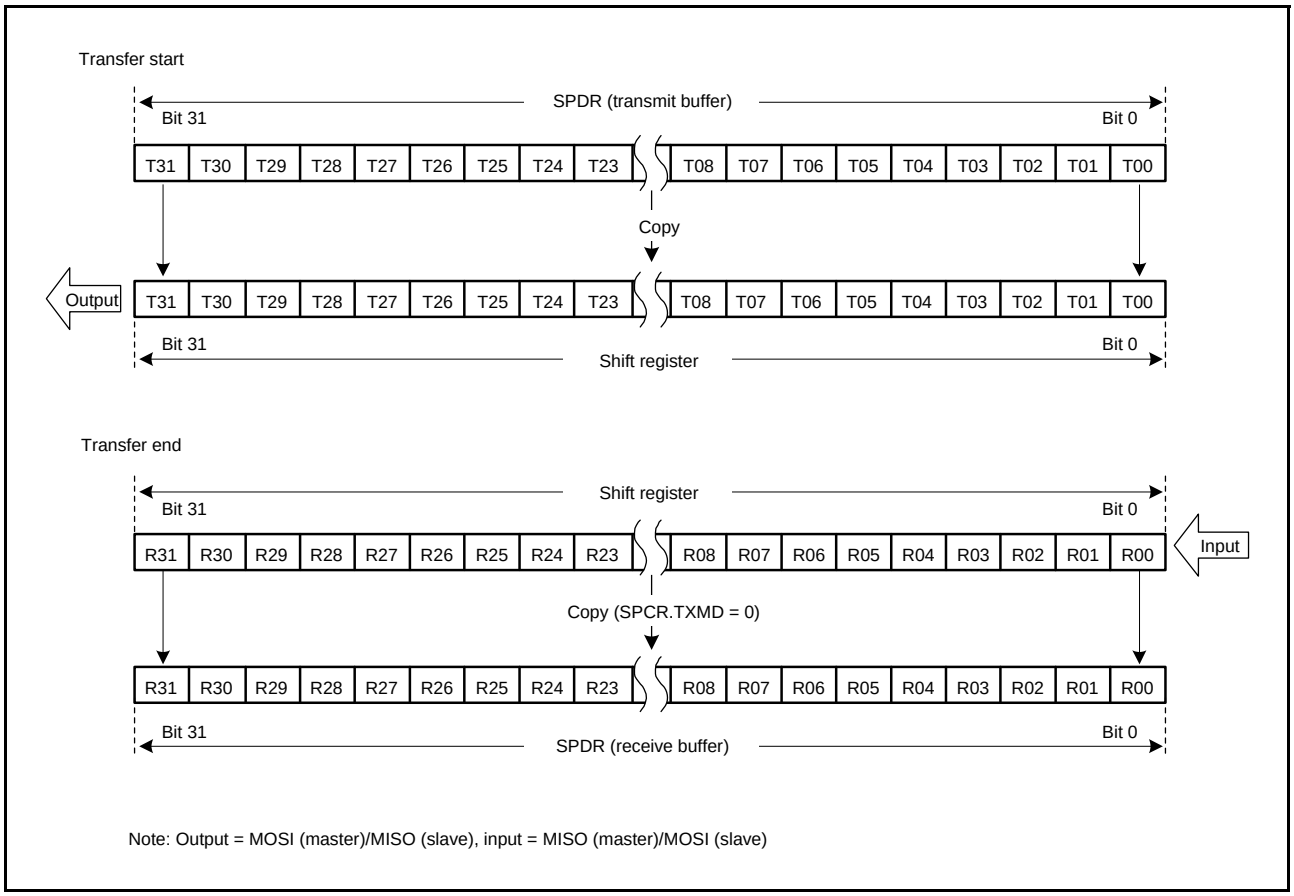


Figure 26.13 MSB First Transfer (1) (32-Bit Data, Parity Function Disabled)

(2) Parity Function is Enabled (SPCR2.SPPE = 1)

Figure 26.14 shows the operation of SPDR and the shift register when the RSPI performs a 32-bit data length MSB-first data transfer with the parity function enabled.

Data T31 to T00 is written to the transmit buffer of SPDR. If the transmit buffer holds data and the shift register is empty, the RSPI converts T00 of the data stored in the transmit buffer of SPDR into the parity bit (P). Then, the RSPI copies the data with the added parity bit (P) to the shift register, and fully populates the shift register. When serial transfer starts, the RSPI outputs data from the MSB (bit 31) of the shift register, and shifts in the data from the LSB (bit 0) of the shift register. When the RSPCK cycles required for the serial transfer of 32 bits have passed, data R31 to P is stored in the shift register. In this state, when performing full-duplex synchronous serial communications (SPCR.TXMD = 0), the RSPI copies the data from the shift register to the receive buffer of SPDR, and empties the shift register.

If another serial transfer is started before data is written to the transmit buffer of SPDR, received data R31 to P is shifted out from the shift register.

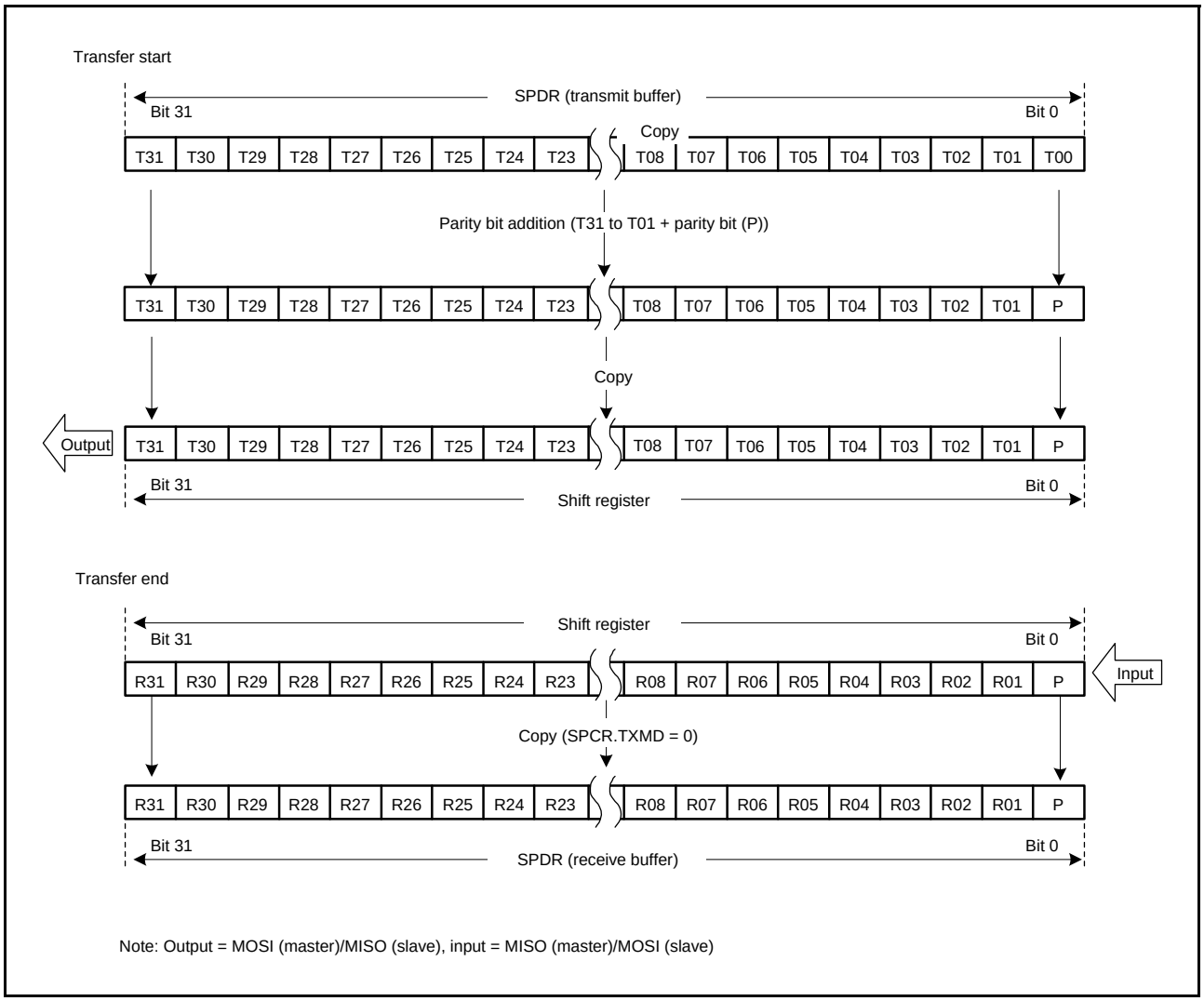


Figure 26.14 MSB First Transfer (2) (32-Bit Data, Parity Function Enabled)

26.3.5.2 MSB First Transfer (24-Bit Data)

(1) Parity Function is Disabled (SPCR2.SPPE = 0)

Figure 26.15 shows the operation of SPDR and the shift register when the RSPI performs a 24-bit data length MSB-first data transfer (as a data transfer example of lengths other than 32 bits) with the parity function disabled.

Data T31 to T00 is written to the transmit buffer of SPDR. If the transmit buffer holds data and the shift register is empty, the RSPI copies the data stored in the transmit buffer of SPDR to the shift register, and fully populates the shift register. When serial transfer starts, the RSPI outputs data from bit 23 of the shift register, and shifts in the data from the LSB (bit 0) of the shift register. When the RSPCK cycles required for the serial transfer of 24 bits have passed, received data R23 to R00 is stored in bits 23 to 0 of the shift register. After completion of the serial transfer, data that existed before the transfer is retained in bits 31 to 24 of the shift register. In this state, when performing full-duplex synchronous serial communications (SPCR.TXMD = 0), the RSPI copies the data from the shift register to the receive buffer of SPDR, and empties the shift register.

If another serial transfer is started before data is written to the transmit buffer of SPDR, received data R23 to R00 is shifted out from the shift register.

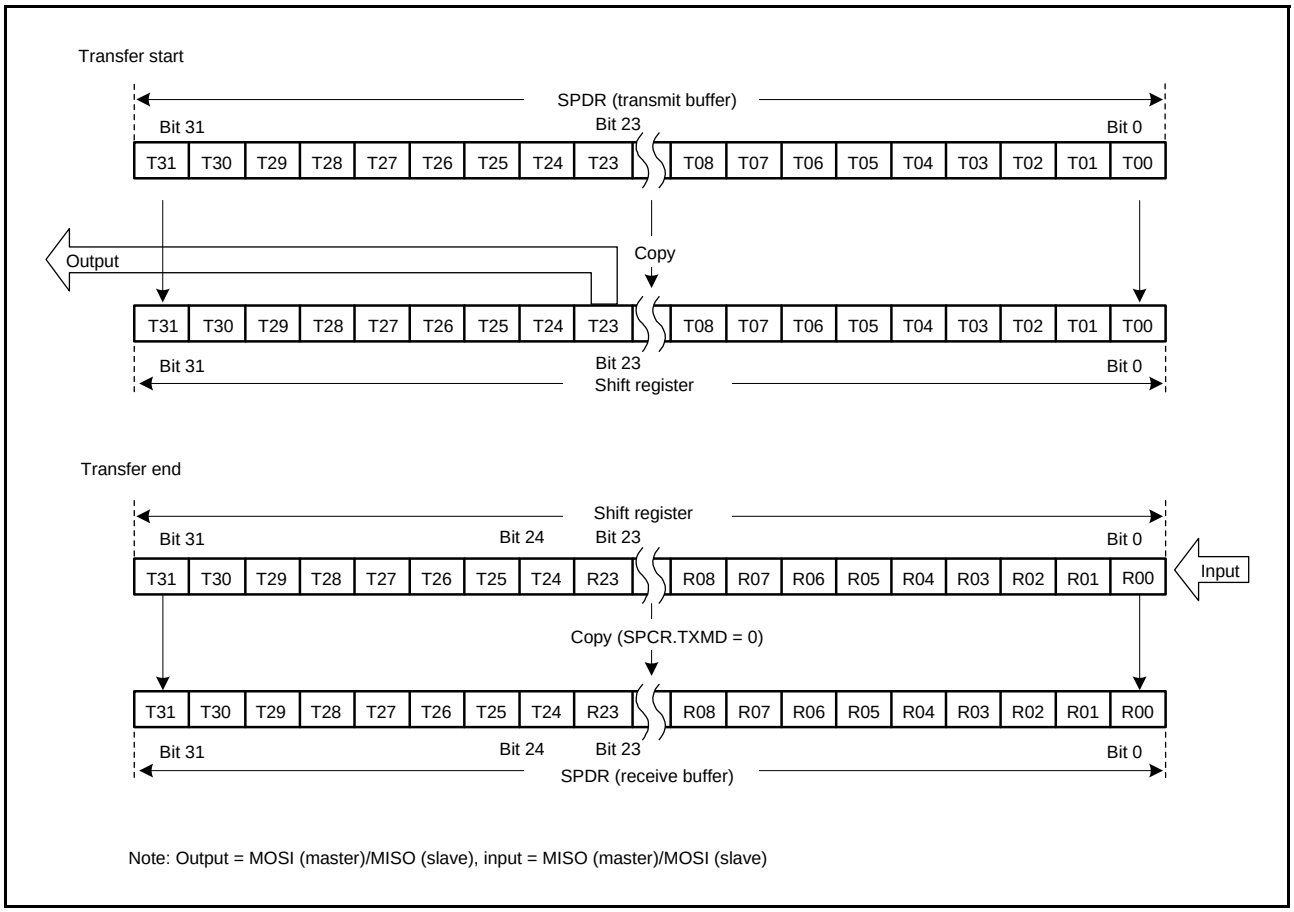


Figure 26.15 MSB First Transfer (1) (24-Bit Data, Parity Function Disabled)

(2) Parity Function is Enabled (SPCR2.SPPE = 1)

Figure 26.16 shows the operation of SPDR and the shift register when the RSPI performs a 24-bit data length MSB-first data transfer (as a data transfer example of lengths other than 32 bits) with the parity function enabled.

Data T31 to T00 is written to the transmit buffer of SPDR. If the transmit buffer holds data and the shift register is empty, the RSPI converts T00 of the data stored in the transmit buffer of SPDR into the parity bit (P). Then, the RSPI copies the data with the added parity bit (P) to the shift register, and fully populates the shift register. When serial transfer starts, the RSPI outputs data from bit 23 of the shift register, and shifts in the data from the LSB (bit 0) of the shift register. When the RSPCK cycles required for the serial transfer of 24 bits have passed, received data R23 to P is stored in bits 23 to 0 of the shift register. After completion of the serial transfer, data that existed before the transfer is retained in bits 31 to 24 of the shift register. In this state, when performing full-duplex synchronous serial communications (SPCR.TXMD = 0), the RSPI copies the data from the shift register to the receive buffer of SPDR, and empties the shift register.

If another serial transfer is started before data is written to the transmit buffer of SPDR, received data R23 to P is shifted out from the shift register.

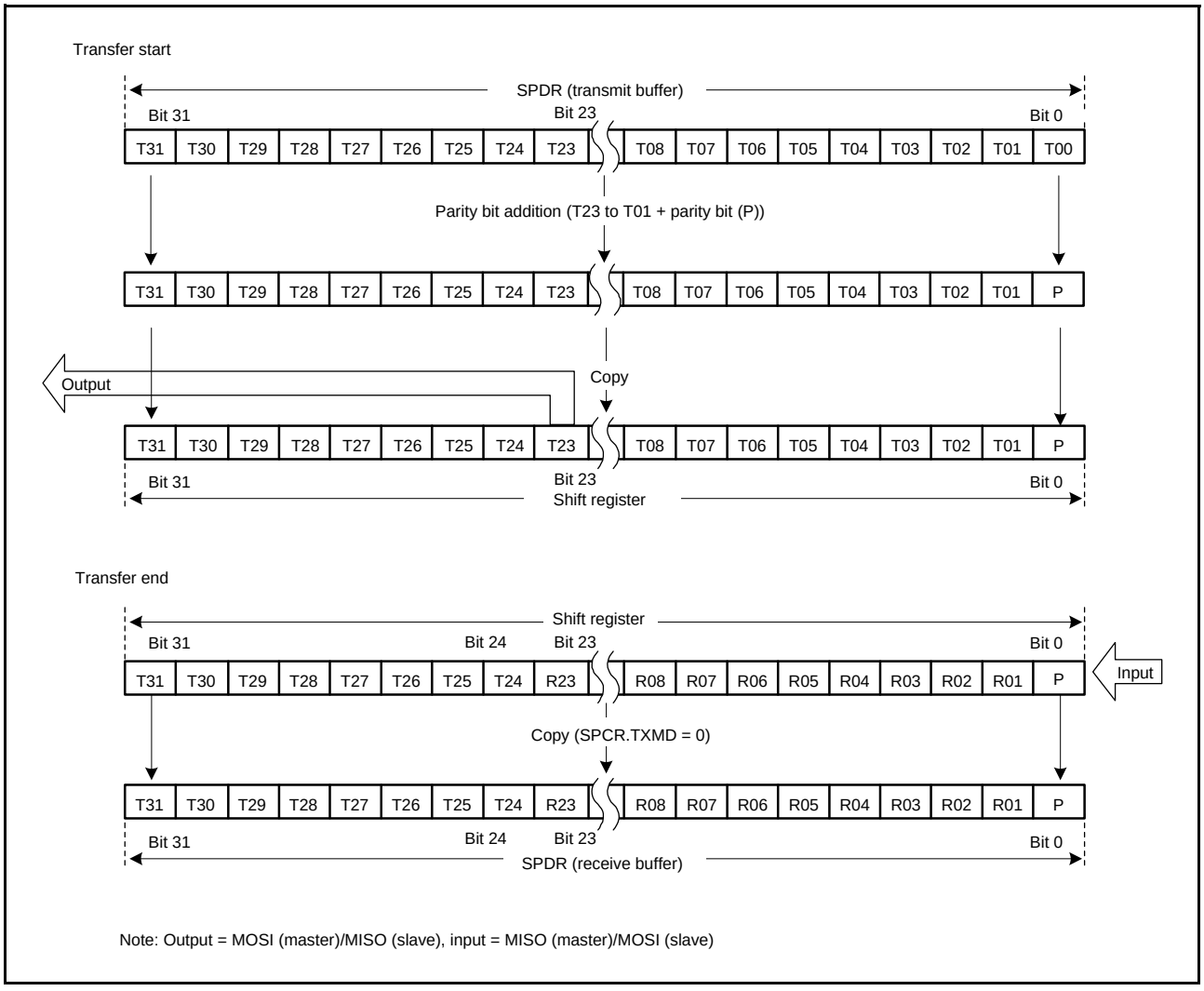


Figure 26.16 MSB First Transfer (2) (24-Bit Data, Parity Function Enabled)

26.3.5.3 LSB First Transfer (32-Bit Data)

(1) Parity Function is Disabled (SPCR2.SPPE = 0)

Figure 26.17 shows the operation of SPDR and the shift register when the RSPI performs a 32-bit data length LSB-first data transfer with the parity function disabled.

Data T31 to T00 is written to the transmit buffer of SPDR. If the transmit buffer holds data and the shift register is empty, the RSPI reverses the order of the bits of the data in the transmit buffer of SPDR, copies it to the shift register, and fully populates the shift register. When serial transfer starts, the RSPI outputs data from the MSB (bit 31) of the shift register, and shifts in the data from the LSB (bit 0) of the shift register. When the RSPCK cycles required for the serial transfer of 32 bits have passed, data R00 to R31 is stored in the shift register. In this state, when performing full-duplex synchronous serial communications (SPCR.TXMD = 0), the RSPI copies the data, in which the order of the bits is reversed, from the shift register to the receive buffer of SPDR, and empties the shift register.

If another serial transfer is started before data is written to the transmit buffer of SPDR, received data R00 to R31 is shifted out from the shift register.

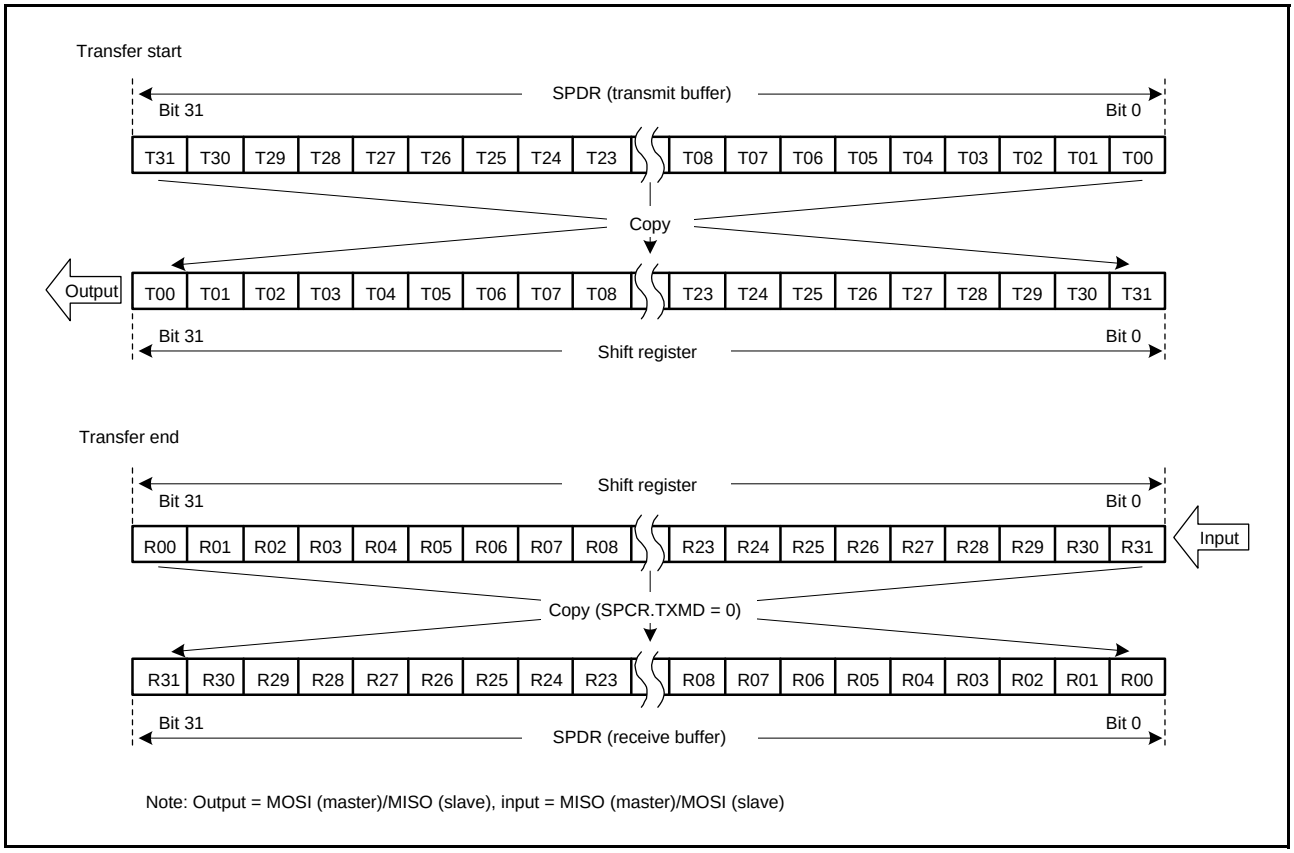


Figure 26.17 LSB First Transfer (1) (32-Bit Data, Parity Function Disabled)

(2) Parity Function is Enabled (SPCR2.SPPE = 1)

Figure 26.18 shows the operation of SPDR and the shift register when the RSPI performs a 32-bit data length LSB-first data transfer with the parity function enabled.

Data T31 to T00 is written to the transmit buffer of SPDR. The RSPI converts T31 of the data stored in the transmit buffer of SPDR into the parity bit (P). If the transmit buffer holds data and the shift register is empty, the RSPI reverses the order of the bits of the data with the added parity bit (P), copies it to the shift register, and fully populates the shift register. When serial transfer starts, the RSPI outputs data from the MSB (bit 31) of the shift register, and shifts in the data from the LSB (bit 0) of the shift register. When the RSPCK cycles required for the serial transfer of 32 bits have passed, data R00 to P is stored in the shift register. In this state, when performing full-duplex synchronous serial communications (SPCR.TXMD = 0), the RSPI copies the data, in which the order of the bits is reversed, from the shift register to the receive buffer of SPDR, and empties the shift register.

If another serial transfer is started before data is written to the transmit buffer of SPDR, received data R00 to P is shifted out from the shift register.

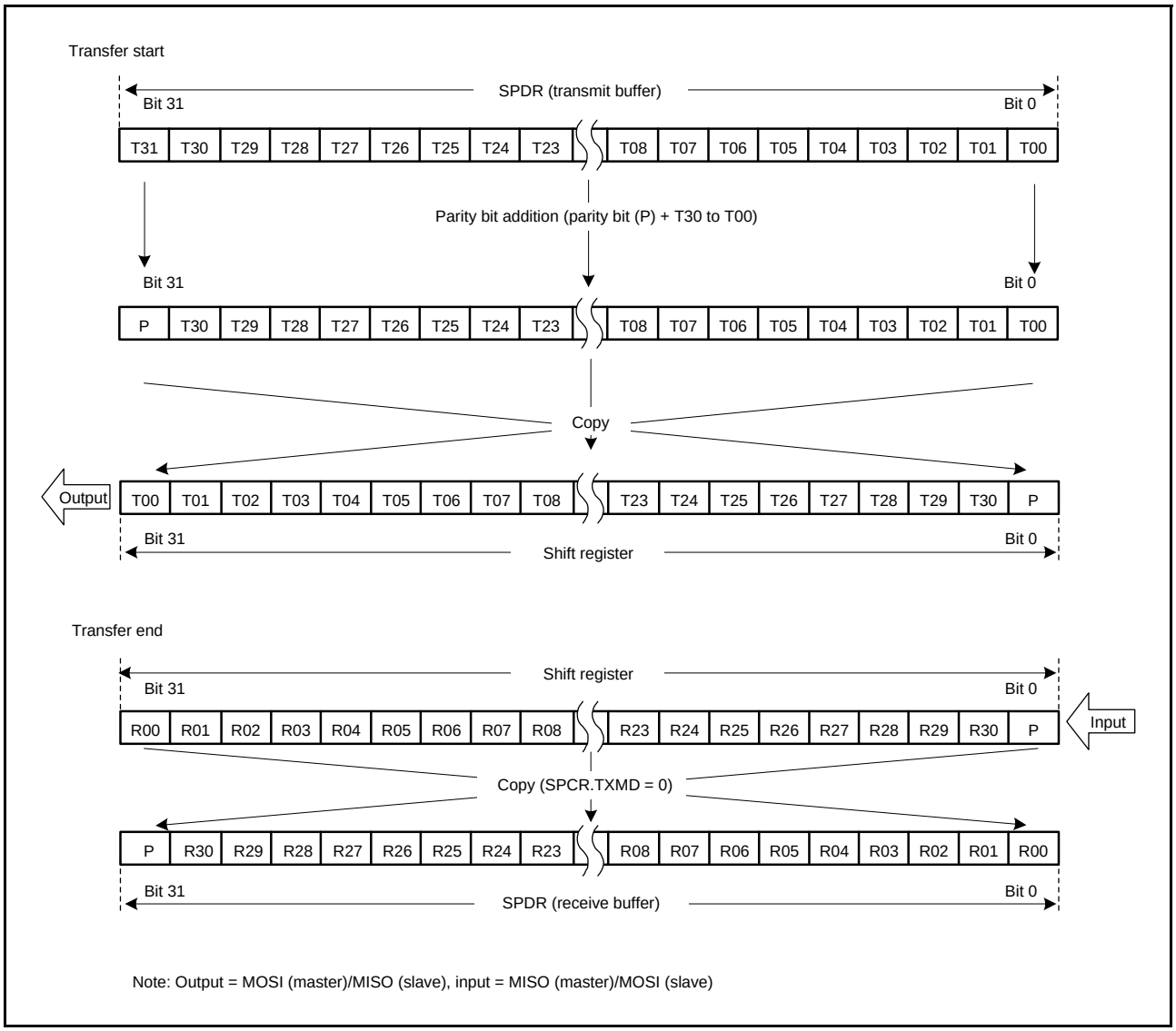


Figure 26.18 LSB First Transfer (2) (32-Bit Data, Parity Function Enabled)

26.3.5.4 LSB First Transfer (24-Bit Data)

(1) Parity Function is Disabled (SPCR2.SPPE = 0)

Figure 26.19 shows the operation of SPDR and the shift register when the RSPI performs a 24-bit data length LSB-first data transfer (as a data transfer example of lengths other than 32 bits) with the parity function disabled.

Data T31 to T00 is written to the transmit buffer of SPDR. If the transmit buffer holds data and the shift register is empty, the RSPI reverses the order of the bits of the data in the transmit buffer of SPDR, copies it to the shift register, and fully populates the shift register. When serial transfer starts, the RSPI outputs data from the MSB (bit 31) of the shift register, and shifts in the data from bit 8 of the shift register. When the RSPCK cycles required for the serial transfer of 24 bits have passed, received data R00 to R23 is stored in bits 31 to 8 of the shift register. After completion of the serial transfer, data that existed before the transfer is retained in bits 7 to 0 of the shift register. In this state, when performing full-duplex synchronous serial communications (SPCR.TXMD = 0), the RSPI copies the data, in which the order of the bits is reversed, from the shift register to the receive buffer of SPDR, and empties the shift register.

If another serial transfer is started before data is written to the transmit buffer of SPDR, received data R00 to R23 is shifted out from the shift register.

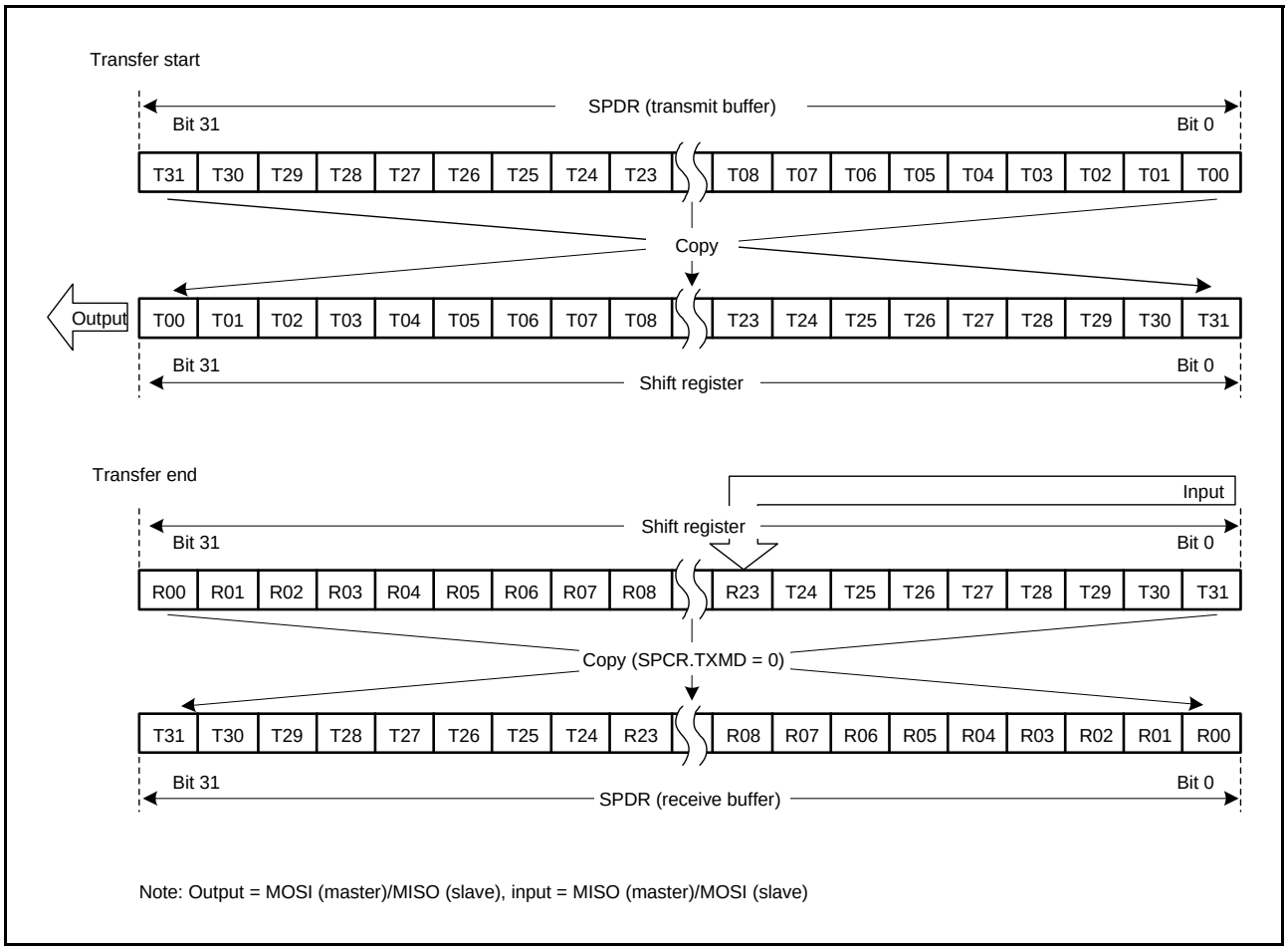


Figure 26.19 LSB First Transfer (1) (24-Bit Data, Parity Function Disabled)

(2) Parity Function is Enabled (SPCR2.SPPE = 1)

Figure 26.20 shows the operation of SPDR and the shift register when the RSPI performs a 24-bit data length LSB-first data transfer (as a data transfer example of lengths other than 32 bits) with the parity function enabled.

Data T31 to T00 is written to the transmit buffer of SPDR. The RSPI converts T23 of the data stored in the transmit buffer of SPDR into the parity bit (P). If the transmit buffer holds data and the shift register is empty, the RSPI reverses the order of the bits of the data with the added parity bit (P), copies it to the shift register, and fully populates the shift register. When serial transfer starts, the RSPI outputs data from the MSB (bit 31) of the shift register, and shifts in the data from bit 8 of the shift register. When the RSPCK cycles required for the serial transfer of 24 bits have passed, received data R00 to P is stored in bits 31 to 8 of the shift register. After completion of the serial transfer, data that existed before the transfer is retained in bits 7 to 0 of the shift register. In this state, when performing full-duplex synchronous serial communications (SPCR.TXMD = 0), the RSPI copies the data, in which the order of the bits is reversed, from the shift register to the receive buffer of SPDR, and empties the shift register.

If another serial transfer is started before data is written to the transmit buffer of SPDR, received data R00 to P is shifted out from the shift register.

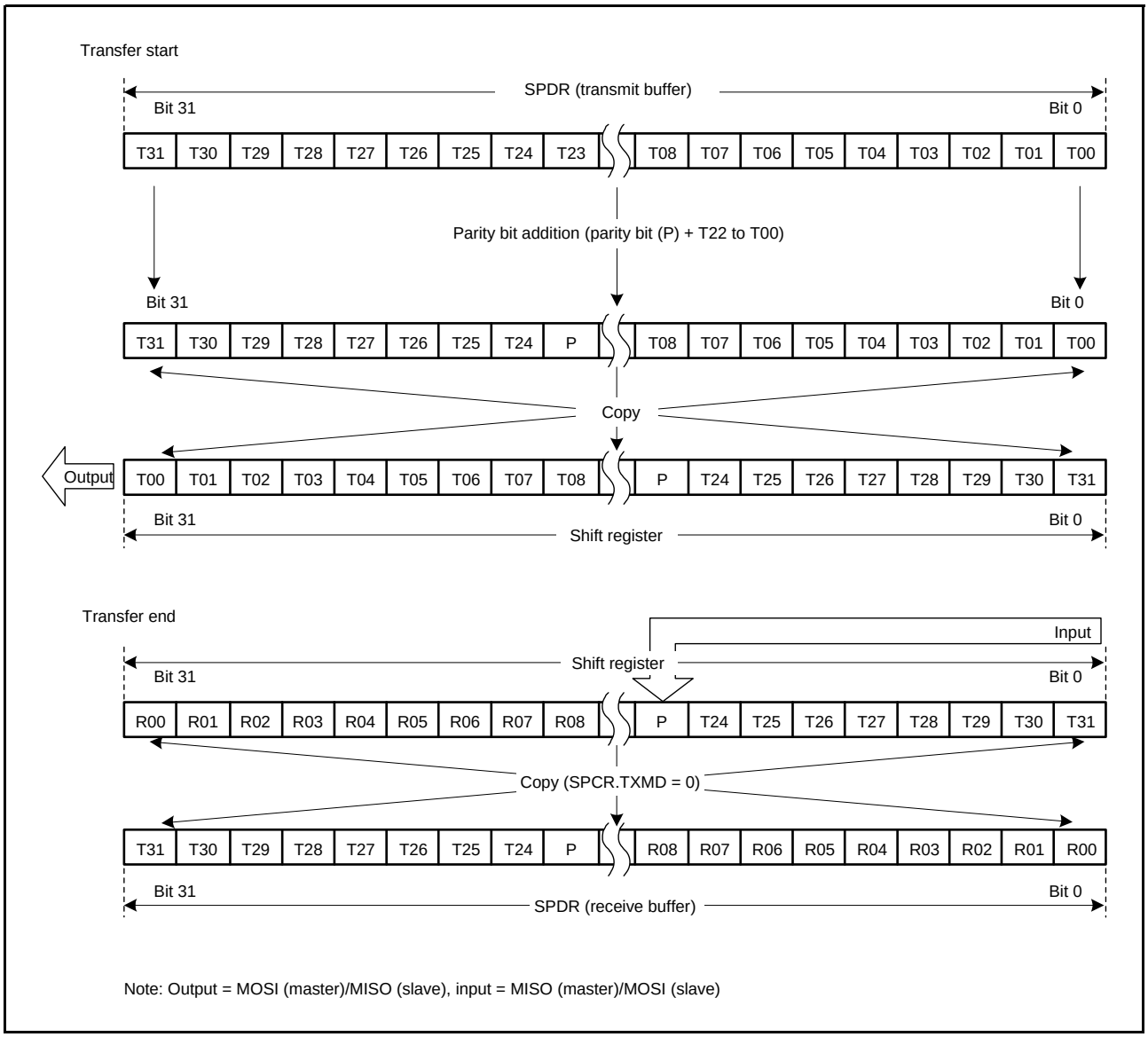


Figure 26.20 LSB First Transfer (2) (24-Bit Data, Parity Function Enabled)

26.3.6 Communications Operating Mode

Full-duplex synchronous serial communications or transmit operations only can be selected by the communications operating mode select bit (TXMD) in the RSPI control register (SPCR). The SPDR access shown in Figure 26.21 and Figure 26.22 indicates the condition of access to the RSPI data register (SPDR), where I denotes an idle cycle and W a write cycle.

26.3.6.1 Full-Duplex Synchronous Serial Communications (SPCR.TXMD = 0)

Figure 26.21 shows an example of operation when the communications operating mode select bit (TXMD) in the RSPI control register (SPCR) is set to 0. In the example of Figure 26.21, the RSPI performs an 8-bit serial transfer in which the SPDCR.SPFC[1:0] bits are 00, the SPCMDm.CPHA bit is 1, and the SPCMDm.CPOL bit is 0. The numbers given under the RSPCK waveform represent the number of RSPCK cycles (i.e., the number of transferred bits).(m = 0 to 7)

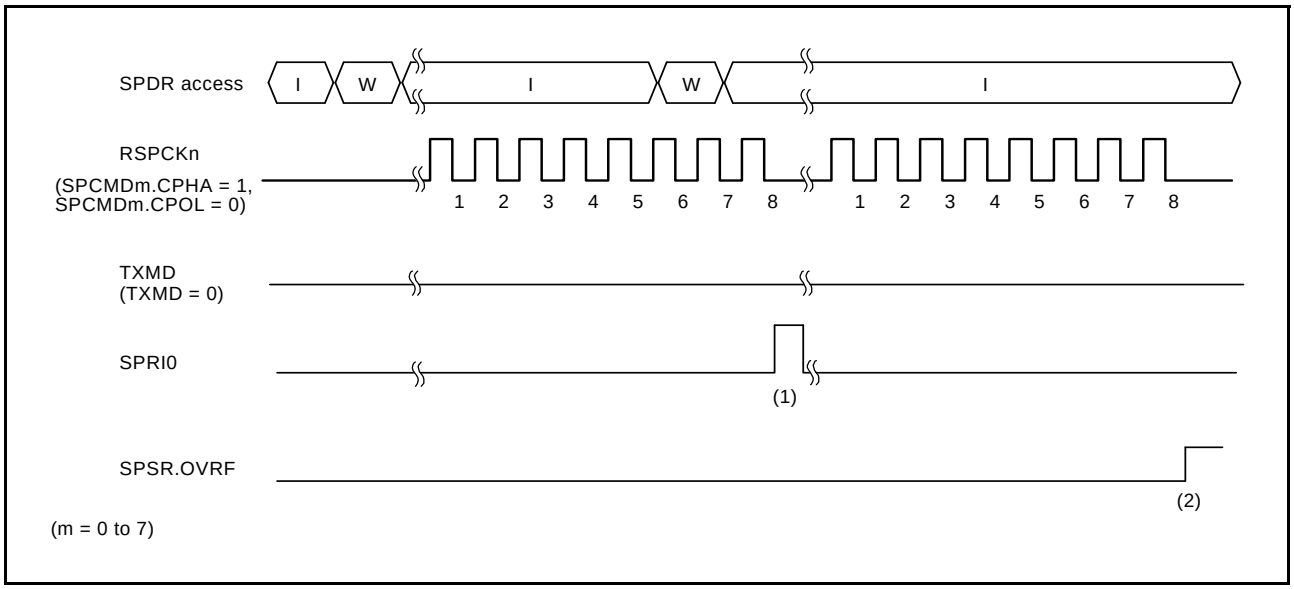


Figure 26.21 Operation Example of SPCR.TXMD = 0

The operation of the flags at timings shown in steps (1) and (2) in the figure is described below.

1. When a serial transfer ends with the receive buffer of SPDR empty, the RSPI generates a receive buffer full interrupt request (SPRI) and copies the received data in the shift register to the receive buffer.
2. When a serial transfer ends with the receive buffer of SPDR holding data that was received in the previous serial transfer, the RSPI sets the OVRF flag in SPSR to 1 and discards the received data in the shift register.

When performing full-duplex synchronous serial communications (SPCR.TXMD = 0), the RSPI transmits transmit data and receives received data. Therefore, the OVRF flag in SPSR is set to 1 at the timings of (1) and (2).

26.3.6.2 Transmit Operations Only (SPCR.TXMD = 1)

Figure 26.22 shows an example of operation when the communications operating mode select bit (TXMD) in the RSPI control register (SPCR) is set to 1. In the example of Figure 26.22, the RSPI performs an 8-bit serial transfer in which the SPDCR.SPFC[1:0] bits are 00, the SPCMDm.CPHA bit is 1, and the SPCMDm.CPOL bit is 0. The numbers given under the RSPCK waveform represent the number of RSPCK cycles (i.e., the number of transferred bits).(m = 0 to 7)

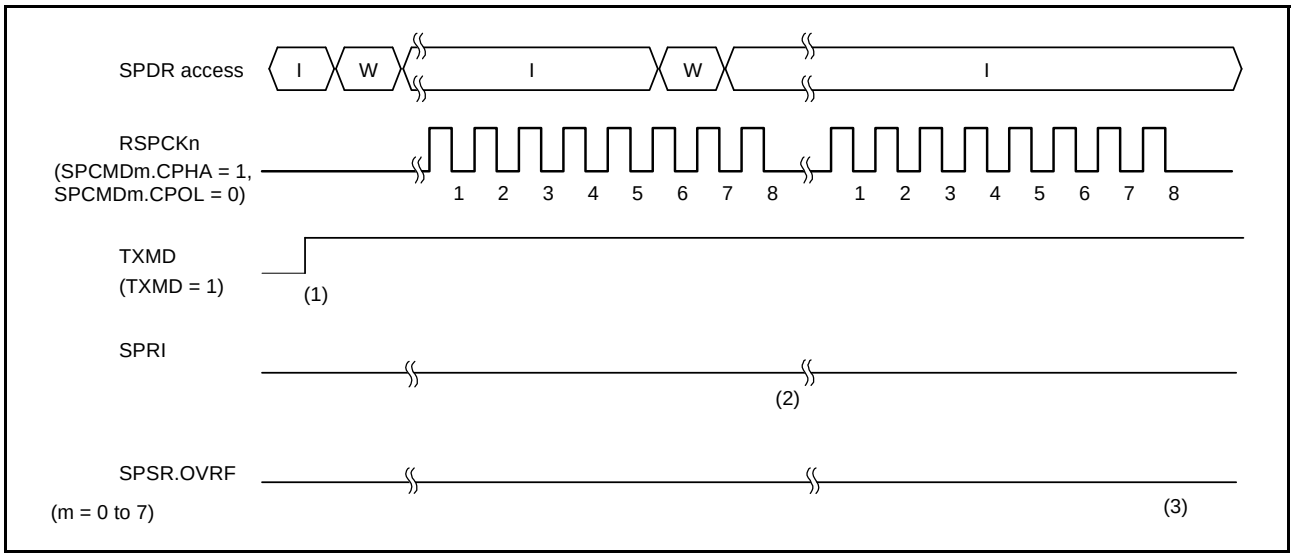


Figure 26.22 Operation Example of SPCR.TXMD = 1

The operation of the flags at timings shown in steps (1) to (3) in the figure is described below.

1. Make sure there is no data left in the receive buffer and the SPSR.OVRF flag is 0 before entering the mode of transmit operations only (SPCR.TXMD = 1).
2. When a serial transfer ends with the receive buffer of SPDR empty, if the mode of transmit operations only is selected (SPCR.TXMD = 1), the RSPI does not copy the data in the shift register to the receive buffer.
3. Since the receive buffer of SPDR does not hold data that was received in the previous serial transfer, even when a serial transfer ends, the SPSR.OVRF flag retains the value of 0, and the data in the shift register is not copied to the receive buffer.

When performing transmit operations only (SPCR.TXMD = 1), the RSPI transmits transmit data but does not receive received data. Therefore, the SPSR.OVRF flag remains cleared to 0 at the timings of (1) to (3).

26.3.7 Transmit Buffer Empty/Receive Buffer Full Interrupts

Figure 26.23 shows an example of operation of the RSPI transmit buffer empty interrupt (SPTI) and the RSPI receive buffer full interrupt (SPRI). The SPDR access shown in Figure 26.23 indicates the condition of access to the RSPI data register (SPDR), where I denotes an idle cycle, W a write cycle, and R a read cycle. In the example of Figure 26.23, the RSPI performs an 8-bit serial transfer in which the SPCR.TXMD bit is 0, the SPDCR.SPFC[1:0] bits are 00, the SPCMDm.CPHA bit is 1, and the SPCMDm.CPOL bit is 0. The numbers given under the RSPCK waveform represent the number of RSPCK cycles (i.e., the number of transferred bits).(m = 0 to 7)

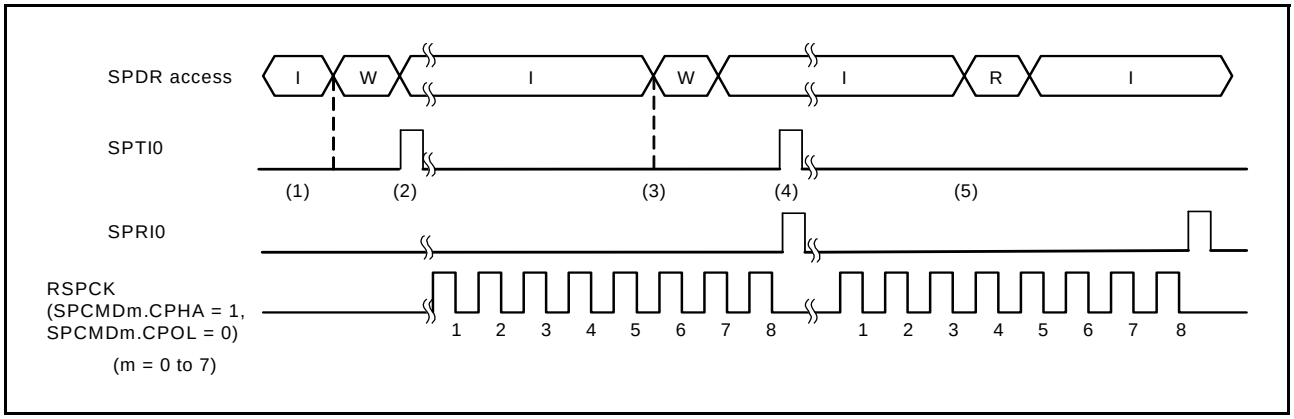


Figure 26.23 Operation Example of SPTI and SPRI Interrupts

The operation of the interrupts at timings shown in steps (1) to (5) in the figure is described below.

1. When transmit data is written to SPDR when the transmit buffer of SPDR is empty (data for the next transfer is not set), the RSPI writes data to the transmit buffer.
2. If the shift register is empty, the RSPI copies the data in the transmit buffer to the shift register and generates a transmit buffer empty interrupt request (SPTI). How a serial transfer is started depends on the mode of the RSPI. For details, see section 26.3.10, SPI Operation, and section 26.3.11, Clock Synchronous Operation.
3. When transmit data is written to SPDR by the transmit buffer empty interrupt routine, the data is transferred to the transmit buffer. Because the data being transferred serially is stored in the shift register, the RSPI does not copy the data in the transmit buffer to the shift register.
4. When the serial transfer ends with the receive buffer of SPDR being empty, the RSPI copies the receive data in the shift register to the receive buffer and generates a receive buffer full interrupt request (SPRI). Because the shift register becomes empty upon completion of serial transfer, when the transmit buffer had been full before the serial transfer ended, the RSPI copies the data in the transmit buffer to the shift register. Even when received data is not copied from the shift register to the receive buffer in an overrun error status, upon completion of the serial transfer, the RSPI determines that the shift register is empty, thus data transfer from the transmit buffer to the shift register is enabled.
5. When SPDR is read by the receive buffer full interrupt routine, the RSPI sends the data in the receive buffer to the bus inside the chip.

If SPDR is written to when the transmit buffer holds data that has not yet been transmitted, the RSPI does not update the data in the transmit buffer. When writing to SPDR, make sure to use a transmit buffer empty interrupt request. To use an RSPI transmit interrupt, set the SPTIE bit in SPCR to 1.
If the RSPI is disabled (the SPE bit in SPCR being 0), set the SPTIE bit in SPCR to 0.
When serial transfer ends with the receive buffer being full, the RSPI does not copy data from the shift register to the receive buffer, and detects an overrun error (see section 26.3.8, Error Detection). To prevent a receive data overrun error, read the received data using a receive buffer full interrupt request before the next serial transfer ends. To use an RSPI receive interrupt, set the SPRIE bit in SPCR to 1.
The status of the transmit/receive buffer can be checked by either using a transmit/receive interrupt or by reading the corresponding IRi.IR flag of the ICU.

26.3.8 Error Detection

In the normal RSPI serial transfer, the data written to the transmit buffer of SPDR is serially transmitted, and the serially received data can be read from the receive buffer of SPDR. If access is made to SPDR, depending on the status of the transmit/receive buffer or the status of the RSPI at the beginning or end of serial transfer, in some cases non-normal transfers can be executed.
If a non-normal transfer operation occurs, the RSPI detects the event as an overrun error, parity error, or mode fault error. Table 26.9 shows the relationship between non-normal transfer operations and the RSPI's error detection function.

Table 26.9 Relationship between Non-Normal Transfer Operations and RSPI Error Detection Function

	Occurrence Condition	RSPI Operation	Error Detection
A	SPDR is written when the transmit buffer is full.	The contents of the transmit buffer are kept. Missing write data.	None
B	Serial transfer is started in slave mode when transmit data is still not loaded on the shift register.	Data received in previous serial transfer is serially transmitted.	None
C	SPDR is read when the receive buffer is empty.	Previously received serial data is output.	None
D	Serial transfer terminates when the receive buffer is full.	The contents of the receive buffer are kept. Missing serial receive data.	Overrun error
E	An incorrect parity bit is received when performing full-duplex synchronous serial communications with the parity function enabled.	The parity error flag is asserted.	Parity error
F	The SSL0 input signal is asserted when the serial transfer is idle in multi-master mode.	Driving of the RSPCK, MOSI, SSL1 to SSL3 output signals is stopped. RSPI function is disabled.	Mode fault error
G	The SSL0 input signal is asserted during serial transfer in multi-master mode.	Serial transfer is suspended. Missing transmit/receive data. Driving of the RSPCK, MOSI, SSL1 to SSL3 output signals is stopped. RSPI function is disabled.	Mode fault error
H	The SSL0 input signal is negated during serial transfer in slave mode.	Serial transfer is suspended. Missing transmit/receive data. Driving of the MISO output signal is stopped. RSPI function is disabled.	Mode fault error

On operation A shown in Table 26.9, the RSPI does not detect an error. To prevent data omission during the writing to SPDR, write operations to SPDR should be executed using a transmit interrupt request.
The RSPI does not detect an error on operation B. In a serial transfer that was started before the shift register was updated, the RSPI sends the data that was received in the previous serial transfer, and does not treat the operation indicated in B as an error. Note that the received data from the previous serial transfer is retained in the receive buffer of SPDR, thus it can be correctly read (if SPDR is not read before the end of the serial transfer, an overrun error may occur).
Similarly, the RSPI does not detect an error on operation C. To prevent extraneous data from being read, SPDR read

operation should be executed using a receive interrupt request.
An overrun error shown in D is described in section 26.3.8.1, Overrun Error. A parity error shown in E is described in section 26.3.8.2, Parity Error. A mode fault error shown in F to H is described in section 26.3.8.3, Mode Fault Error.
For the transmit and receive interrupts, refer to section 26.3.7, Transmit Buffer Empty/Receive Buffer Full Interrupts.

26.3.8.1 Overrun Error

If a serial transfer ends when the receive buffer of SPDR is full, the RSPI detects an overrun error, and sets the OVRF flag in SPSR to 1. When the SPSR.OVRF flag is 1, the RSPI does not copy data from the shift register to the receive buffer so that the data prior to the occurrence of the error is retained in the receive buffer. To set the OVRF flag in SPSR to 0, write 0 to the SPSR.OVRF flag after the CPU has read SPSR with the SPSR.OVRF flag set to 1.
Figure 26.24 shows an example of operation of the SPSR.OVRF flag. The SPSR and SPDR accesses shown in Figure 26.24 indicates the condition of accesses to SPSR and SPDR, respectively, where I denotes an idle cycle, W a write cycle, and R a read cycle. In the example of Figure 26.24, the RSPI performs an 8-bit serial transfer in which the SPCMDm.CPHA bit is 1 and the SPCMDm.CPOL bit is 0. The numbers given under the RSPCK waveform represent the number of RSPCK cycles (i.e., the number of transferred bits).(m = 0 to 7)

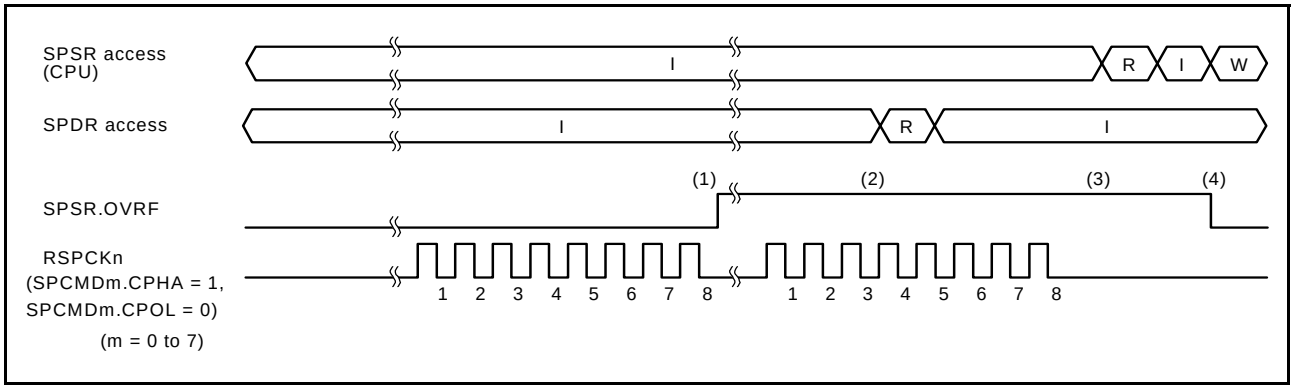


Figure 26.24 Operation Example of OVRF Flag

The operation of the flags at the timing shown in steps (1) to (4) in the figure is described below.

1. If a serial transfer terminates with the receive buffer full, the RSPI detects an overrun error, and sets the SPSR.OVRF flag to 1. The RSPI does not copy the data in the shift register to the receive buffer. Even if the SPCR2.SPPE bit is 1, parity errors are not detected. In master mode, the RSPI copies the pointer value to SPCMDm to the SPSSR.SPECM[2:0] bits.(m = 0 to 7)
2. When SPDR is read, the RSPI outputs the data in the receive buffer to an internal bus. The receive buffer becoming empty does not clear the SPSR.OVRF flag.
3. If the serial transfer ends with the SPSR.OVRF flag being 1 (an overrun error), the RSPI does not copy the data in the shift register to the receive buffer. Even if the SPCR2.SPPE bit is 1, parity errors are not detected. When in master mode, the RSPI does not update the SPSSR.SPECM[2:0] bits. When in an overrun error state and the RSPI does not copy the received data from the shift register to the receive buffer, upon termination of the serial transfer, the RSPI determines that the shift register is empty; in this manner, data transfer from the transmit buffer to the shift register is enabled.
4. If the CPU writes the value 0 to the SPSR.OVRF flag after reading SPSR when the SPSR.OVRF flag is 1, the RSPI clears the SPSR.OVRF flag.

The occurrence of an overrun can be checked either by reading SPSR or by using an RSPI error interrupt and reading SPSR. When using an RSPI error interrupt, set the SPEIE bit in the RSPI control register (SPCR) to 1. When executing a

serial transfer without using an RSPI error interrupt, measures should be taken to ensure the early detection of overrun errors, such as reading SPSR immediately after SPDR is read. When the RSPI is used in master mode, the pointer value to SPCMD at the occurrence of the error can be checked by reading the SPSSR.SPECM[2:0] bits.
If an overrun error occurs and the SPSR.OVRF flag is set to 1, normal reception operations cannot be performed until the SPSR.OVRF flag is cleared. The SPSR.OVRF flag is cleared to 0 under the following condition:
[Clearing condition]

- The CPU reads SPSR when the SPSR.OVRF flag is 1, and then writes the value 0 to the SPSR.OVRF flag.

26.3.8.2 Parity Error

If full-duplex synchronous serial communications is performed with the TXMD bit in the RSPI control register (SPCR) cleared to 0 and the SPPE bit in RSPI control register 2 (SPCR2) set to 1, when serial transfer ends, the RSPI checks whether there are parity errors. Upon detecting a parity error in the received data, the RSPI sets the PERF flag in the RSPI status register (SPSR) to 1. Since the RSPI does not copy the data in the shift register to the receive buffer when the OVRF flag is set to 1, parity error detection is not performed for the received data. To set the PERF bit in SPSR to 0, write 0 to the SPSR.PERF flag after the CPU has read SPSR with the SPSR.PERF flag set to 1.
Figure 26.25 shows an example of operation of the OVRF and PERF bits in SPSR. The SPSR access shown in Figure 26.25 indicates the condition of access to SPSR, where I denotes an idle cycle, W a write cycle, and R a read cycle. In the example of Figure 26.25, full-duplex synchronous serial communications is performed while the TXMD bit in the RSPI control register (SPCR) is 0 and the SPPE bit in RSPI control register 2 (SPCR2) is 1. The RSPI performs an 8-bit serial transfer in which the SPCMDm.CPHA bit is 1 and the SPCMDm.CPOL bit is 0. The numbers given under the RSPCK waveform represent the number of RSPCK cycles (i.e., the number of transferred bits).(m = 0 to 7)

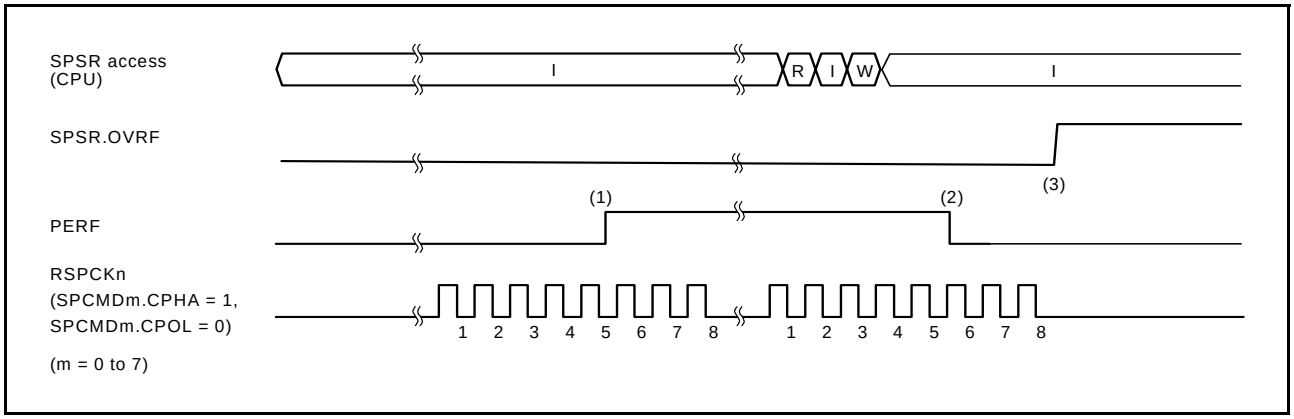


Figure 26.25 Operation Example of SPSR.PERF Flag

The operation of the flags at the timing shown in steps (1) to (3) in the figure is described below.

1. If a serial transfer terminates with the RSPI not detecting an overrun error, the RSPI copies the data in the shift register to the receive buffer. The RSPI judges the received data at this timing, and sets the SPSR.PERF flag to 1 if a parity error is detected. In master mode, the RSPI copies the pointer value to SPCMDm to the SPSSR.SPECM[2:0] bits.(m = 0 to 7)
2. If the CPU writes the value 0 to the SPSR.PERF flag after reading SPSR when the SPSR.PERF bit is 1, the RSPI clears the SPSR.OVRF flag.
3. When the RSPI detects an overrun error and serial transfer is terminated, the data in the shift register is not copied to the receive buffer. The RSPI does not perform parity error detection at this timing.

The occurrence of a parity error can be checked either by reading SPSR or by using an RSPI error interrupt and reading SPSR. When using an RSPI error interrupt, set the SPEIE bit in the RSPI control register (SPCR) to 1. When executing a serial transfer without using an RSPI error interrupt, measures should be taken to ensure the early detection of parity

errors, such as reading SPSR immediately after SPDR is read. When the RSPI is used in master mode, the pointer value to SPCMDm at the occurrence of the error can be checked by reading the SPSSR.SPECM[2:0] bits.
The SPSR.PERF flag is cleared to 0 under the following condition:
[Clearing condition]

- The CPU reads SPSR when the SPSR.PERF flag is 1, and then writes the value 0 to the SPSR.PERF flag.

26.3.8.3 Mode Fault Error

The RSPI operates in multi-master mode when the SPCR.MSTR bit is 1, the SPCR.SPMS bit is 0, and the SPCR.MODFEN bit is 1. If the active level is input with respect to the SSL0 input signal of the RSPI in multi-master mode, the RSPI detects a mode fault error irrespective of the status of the serial transfer, and sets the MODF bit in the RSPI status register (SPSR) to 1. Upon detecting the mode fault error, the RSPI copies the value of the pointer to SPCMDm to the SPSSR.SPECM[2:0] bits. The active level of the SSL0 signal is determined by the SSL0P bit in the RSPI slave select polarity register (SSLP).(m = 0 to 7)
When the SPCR.MSTR bit is 0, the RSPI operates in slave mode. The RSPI detects a mode fault error if the SPCR.MODFEN bit in the RSPI in slave mode is 1, and the SPCR.SPMS bit is 0, and if the SSL0 input signal is negated during the serial transfer period (from the time the driving of valid data is started to the time the final valid data is fetched).
Upon detecting a mode fault error, the RSPI stops driving of the output signals and clears the SPE bit in SPCR to 0 (see section 26.3.9, Initializing RSPI). In the case of multi-master configuration, detection of a mode fault error is used to stop driving of the output signals and the RSPI function, which allows the master right to be released.
The occurrence of a mode fault error can be checked either by reading SPSR or by using an RSPI error interrupt and reading SPSR. When using an RSPI error interrupt, set the SPEIE bit in the RSPI control register (SPCR) to 1. To detect a mode fault error without using an RSPI error interrupt, it is necessary to poll SPSR. When using the RSPI in master mode, the pointer value to SPCMDm at the occurrence of the error can be checked by reading the SPSSR.SPECM[2:0] bits.
When the SPSR.MODF flag is 1, the RSPI ignores the writing of the value 1 to the SPCR.SPE bit by the CPU. To enable the RSPI function after the detection of a mode fault error, the SPSR.MODF flag must be set to 0.
The SPSR.MODF flag is cleared to 0 under the following condition:
[Clearing condition]

- The CPU reads SPSR when the SPSR.MODF flag is 1, and then writes the value 0 to the SPSR.MODF flag.

26.3.9 Initializing RSPI

If the CPU writes the value 0 to the SPE bit in the RSPI control register (SPCR) or the RSPI clears the SPCR.SPE bit to 0 because of the detection of a mode fault error, the RSPI disables the RSPI function, and initializes some of the module functions. When a system reset is generated, the RSPI initializes all of the module functions. The following describes initialization by the clearing of the SPCR.SPE bit and initialization by a system reset.

26.3.9.1 Initialization by Clearing the SPE Bit

When the SPE bit in SPCR is cleared, the RSPI performs the following initialization:

- Suspending any serial transfer that is being executed
- Stopping the driving of output signals (Hi-Z) in slave mode
- Initializing the internal state of the RSPI
- Initializing the transmit buffer of the RSPI

Initialization by the clearing of the SPCR.SPE bit does not initialize the control bits of the RSPI. For this reason, the RSPI can be started in the same transfer mode as prior to the initialization if the CPU resets the value 1 to the SPCR.SPE bit.
The OVRF and MODF flags in SPSR are not initialized, nor is the value of the RSPI sequence status register (SPSSR) initialized. For this reason, even after the RSPI is initialized, data from the receive buffer can be read in order to check the status of error occurrence during an RSPI transfer.
The transmit buffer is initialized to an empty state. Therefore, if the SPTIE bit in SPCR is set to 1 after RSPI initialization, an RSPI transmit interrupt is generated. When the RSPI is initialized by the CPU, in order to disable any RSPI transmit interrupt, the value 0 should be written to the SPCR.SPTIE bit simultaneously with the writing of the value 0 to the SPCR.SPE bit. To disable any RSPI transmit interrupt after a mode fault error is detected, use an error handling routine to write the value 0 to the SPCR.SPTIE bit.

26.3.9.2 System Reset

The initialization by a system reset completely initializes the RSPI through the initialization of all bits for controlling the RSPI, initialization of the status bits, and initialization of data registers, in addition to the requirements described in section 26.3.9.1, Initialization by Clearing the SPE Bit.

26.3.10 SPI Operation

26.3.10.1 Master Mode Operation

The only difference between single-master mode operation and multi-master mode operation lies in mode fault error detection (see section 26.3.8, Error Detection). When operating in single-master mode, the RSPI does not detect mode fault errors whereas the RSPI running in multi-master mode does detect mode fault errors. This section explains operations that are common to single-master mode and multi-master mode.

(1) Starting a Serial Transfer

The RSPI updates the data in the transmit buffer when data is written to the RSPI data register (SPDR) with the RSPI transmit buffer being empty (data for the next transfer is not set). If the shift register is empty due to the writing to SPDR, the RSPI copies the data in the transmit buffer to the shift register and starts a serial transfer. Upon copying transmit data to the shift register, the RSPI changes the status of the shift register to "full", and upon termination of serial transfer, it changes the status of the shift register to "empty". The status of the shift register cannot be referenced from the CPU.
For details on the RSPI transfer format, see section 26.3.4, Transfer Format. The polarity of the SSL output pins depends on the settings in the RSPI slave select polarity register (SSLP).

(2) Terminating a Serial Transfer

Irrespective of the CPHA bit in the RSPI command register (SPCMD), the RSPI terminates the serial transfer after transmitting an RSPCK edge corresponding to the final sampling timing. If free space is available in the receive buffer, upon termination of serial transfer, the RSPI copies data from the shift register to the receive buffer of the RSPI data register (SPDR).
It should be noted that the final sampling timing varies depending on the bit length of transfer data. In master mode, the RSPI data length depends on the SPCMD.SPB[3:0] bit setting. The polarity of the SSL output pin depends on the settings in the RSPI slave select polarity register (SSLP).
For details on the RSPI transfer format, see section 26.3.4, Transfer Format. (m = 0 to 7)

(3) Sequence Control

The transfer format that is employed in master mode is determined by SPSCR, SPCMDm, SPBR, SPCKD, SSLND, and SPND.
SPSCR is a register used to determine the sequence configuration for serial transfers that are executed by the RSPI in master mode. The following items are set in RSPI command registers SPCMDm: SSL pin output signal value, MSB/LSB first, data length, some of the bit rate settings, RSPCK polarity/phase, whether SPCKD is to be referenced, whether SSLND is to be referenced, and whether SPND is to be referenced. SPBR holds some of the bit rate settings; SPCKD, an RSPI clock delay value; SSLND, an SSL negation delay; and SPND, a next-access delay value.
According to the sequence length that is assigned to SPSCR, the RSPI makes up a sequence comprised of a part or all of SPCMDm. The RSPI contains a pointer to the SPCMDm that makes up the sequence. The CPU can check the value of this pointer by reading the SPSSR.SPCP[2:0] bits. When the SPCR.SPE bit is set to 1 and the RSPI function is enabled, the RSPI loads the pointer to the commands in SPCMD0, and incorporates the SPCMD0 settings into the transfer format at the beginning of serial transfer.
The RSPI increments the pointer each time the next-access delay period for a data transfer ends. Upon completion of the serial transfer that corresponds to the final command comprising the sequence, the RSPI sets the pointer in SPCMD0, and in this manner the sequence is executed repeatedly.(m = 0 to 7)

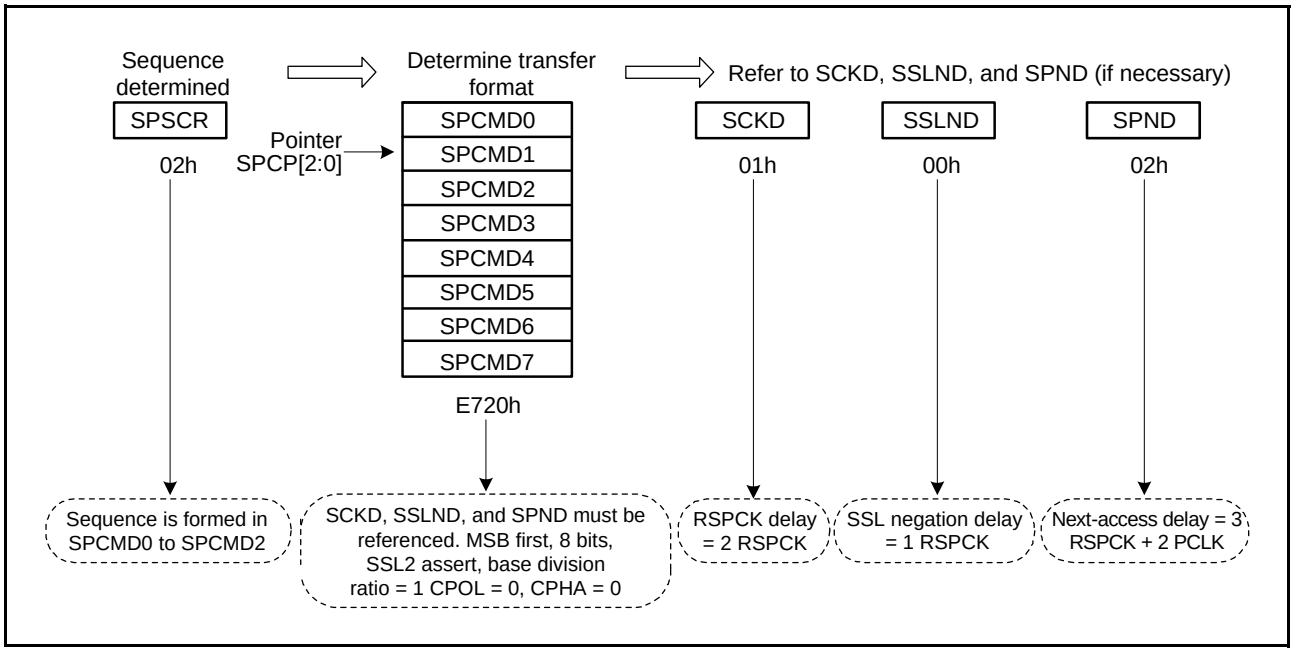


Figure 26.26 Determination Procedure of Serial Transfer Mode in Master Mode (SPI Operation)

(4) Burst Transfer

If the SSLKP bit in the RSPI command register (SPCMD) (m = 0 to 7)that the RSPI references during the current serial transfer is 1, the RSPI keeps the SSL signal level during the serial transfer until the beginning of the SSL signal assertion for the next serial transfer. If the SSL signal level for the next serial transfer is the same as the SSL signal level for the current serial transfer, the RSPI can execute continuous serial transfers while keeping the SSL signal assertion status (burst transfer).

Figure 26.27 shows an example of an SSL signal operation for the case where a burst transfer is implemented using SPCMD0 and SPCMD1 settings. The text below explains the RSPI operations (1) to (7) as shown in Figure 26.27. It should be noted that the polarity of the SSL output signal depends on the settings in the RSPI slave select polarity register (SSLP).

Based on SPCMD0, the RSPI asserts the SSL signal and inserts RSPCK delays.

The RSPI executes serial transfers according to SPCMD0.

The RSPI inserts SSL negation delays.

Because the SSLKP bit in SPCMD0 is 1, the RSPI keeps the SSL signal value on SPCMD0. This period is sustained, at the shortest, for a period equal to the next-access delay of SPCMD0. If the shift register is empty after the passage of a minimum period, this period is sustained until the transmit data is stored in the shift register for the next transfer.

Based on SPCMD1, the RSPI asserts the SSLn signal and inserts RSPCK delays.

The RSPI executes serial transfers according to SPCMD1.

Because the SSLKP bit in SPCMD1 is 0, the RSPI negates the SSL signal. In addition, a next-access delay is inserted according to SPCMD1.

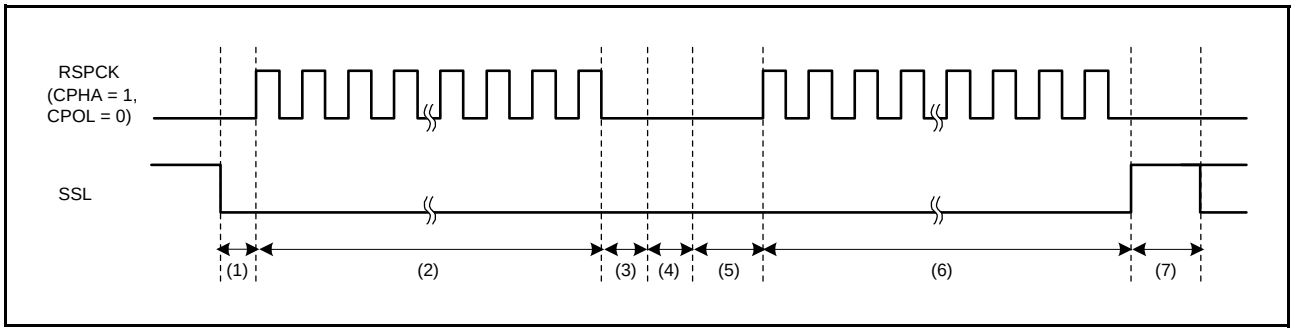


Figure 26.27 Example of Burst Transfer Operation using SPCMDm.SSLKP Bit (m = 0 to 7)

If the SSL signal output settings in the SPCMDm in which 1 is assigned to the SSLKP bit are different from the SSL signal output settings in the SPCMDm to be used in the next transfer, the RSPI switches the SSL signal status to SSL signal assertion ((5) in Figure 26.27) corresponding to the command for the next transfer. Note that if such an SSL signal switching occurs, the slaves that drive the MISO signal compete, and collision of signal levels may occur.
The RSPI in master mode references the SSL signal operation within the module for the case where the SSLKP bit is not used. Even when the SPCMDm.CPHA bit is 0, the RSPI can accurately start serial transfers by asserting the SSL signal for the next transfer. For this reason, burst transfers in master mode can be executed irrespective of SPCMDm.CPHA bit settings (see section 26.3.10.2, Slave Mode Operation).

(5) RSPCK Delay (t1)

The RSPCK delay value of the RSPI in master mode depends on the SPCMDm.SCKDEN bit (m = 0 to 7) setting and the SPCKD setting. The RSPI determines the SPCMDm to be referenced during serial transfer by pointer control, and determines an RSPCK delay value during serial transfer by using the SCKDEN bit in the selected SPCMDm and SPCKD, as shown in Table 26.10. For a definition of RSPCK delay, see section 26.3.4, Transfer Format.

Table 26.10 Relationship among SPCMDm.SCKDEN Bit, SPCKD, and RSPCK Delay Value

SPCMDm.SCKDEN Bit	SPCKD.SCKDL[2:0] Bit	RSPCK Delay Value
0	000 to 111	1 RSPCK
1	000	1 RSPCK
	001	2 RSPCK
	010	3 RSPCK
	011	4 RSPCK
	100	5 RSPCK
	101	6 RSPCK
	110	7 RSPCK
	111	8 RSPCK

(m = 0 to 7)

(6) SSL Negation Delay (t2)

The SSL negation delay value of the RSPI in master mode depends on the SPCMDm.SLNDEN bit (m = 0 to 7) setting and the SSLND setting. The RSPI determines the SPCMDm to be referenced during serial transfer by pointer control, and determines an SSL negation delay value during serial transfer by using the SLNDEN bit in the selected SPCMDm and SSLND, as shown in Table 26.11. For a definition of SSL negation delay, see section 26.3.4, Transfer Format.

Table 26.11 Relationship among SPCMDm.SCKDEN Bit, SSLND, and SSL Negation Delay Value

SPCMDm.SLNDEN Bit	SSLND.SLNDL[2:0] Bit	SSL Negation Delay Value
0	000 to 111	1 RSPCK
1	000	1 RSPCK
	001	2 RSPCK
	010	3 RSPCK
	011	4 RSPCK
	100	5 RSPCK
	101	6 RSPCK
	110	7 RSPCK
	111	8 RSPCK

(m = 0 to 7)

(7) Next-Access Delay (t3)

The next-access delay value of the RSPI in master mode depends on the SPCMDm.SPNDEN bit (m = 0 to 7) setting and the SPND setting. The RSPI determines the SPCMDm to be referenced during serial transfer by pointer control, and determines a next-access delay value during serial transfer by using the SPNDEN bit in the selected SPCMDm and SPND, as shown in Table 26.12. For a definition of next-access delay, see section 26.3.4, Transfer Format.

Table 26.12 Relationship among SPCMDm.SPNDEN Bit, SPND, and Next-Access Delay Value

Table 26.12 Relationship among SPCMDm.SPNDEN Bit, SPND, and Next-Access Delay Value

SPCMDm.SPNDEN Bit	SPND.SPNDL[2:0] Bit	Next-Access Delay Value
0	000 to 111	1 RSPCK + 2 PCLK
1	000	1 RSPCK + 2 PCLK
	001	2 RSPCK + 2 PCLK
	010	3 RSPCK + 2 PCLK
	011	4 RSPCK + 2 PCLK
	100	5 RSPCK + 2 PCLK
	101	6 RSPCK + 2 PCLK
	110	7 RSPCK + 2 PCLK
	111	8 RSPCK + 2 PCLK

(m = 0 to 7)

(8) Initialization Flowchart

Figure 26.28 is a flowchart illustrating an example of initialization in SPI operation when the RSPI is used in master mode. For a description of how to set up the interrupt controller, DTC, and input/output ports, see the descriptions given in the individual blocks.

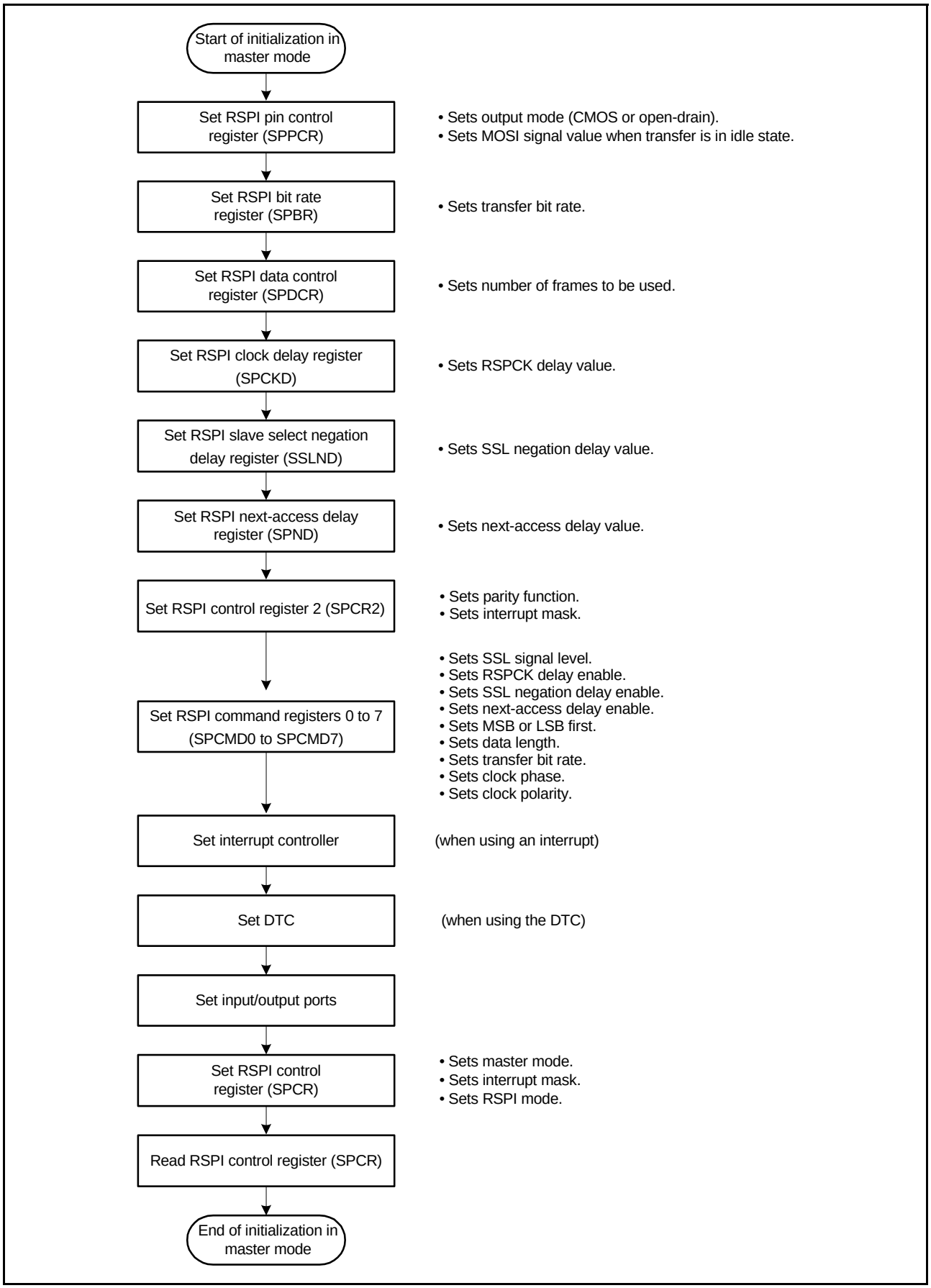
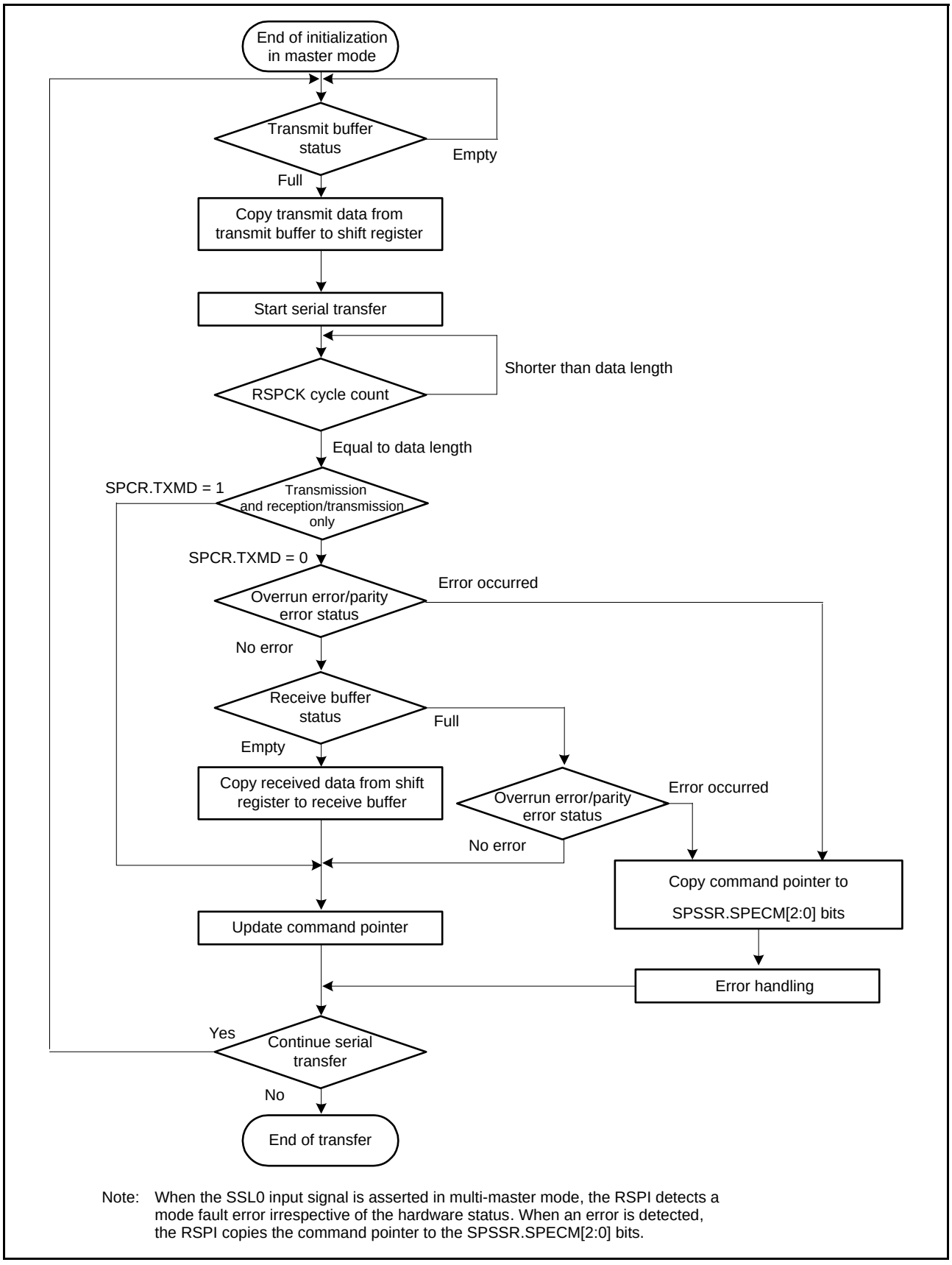


Figure 26.28 Example of Initialization Flowchart in Master Mode (SPI Operation)

(9) Transfer Operation Flowchart

Figure 26.29 is a flowchart illustrating a transfer in SPI operation when the RSPI is used in master mode.



Note: When the SSL0 input signal is asserted in multi-master mode, the RSPI detects a mode fault error irrespective of the hardware status. When an error is detected, the RSPI copies the command pointer to the SPSSR.SPECM[2:0] bits.

Figure 26.29 Transfer Operation Flowchart in Master Mode (SPI Operation)

26.3.10.2 Slave Mode Operation

(1) Starting a Serial Transfer

If the SPCMD0.CPHA bit is 0, when detecting an SSL0 input signal assertion, the RSPI needs to start driving valid data to the MISO output signal. For this reason, when the CPHA bit is 0, the assertion of the SSL0 input signal triggers the start of a serial transfer.
If the SPCMD0.CPHA bit is 1, when detecting the first RSPCK edge in an SSL0 signal asserted condition, the RSPI needs to start driving valid data to the MSO output signal. For this reason, when the CPHA bit is 1, the first RSPCK edge in an SSL0 signal asserted condition triggers the start of a serial transfer.
When detecting the start of a serial transfer in a condition in which the shift register is empty, the RSPI changes the status of the shift register to "full", so that data cannot be copied from the transmit buffer to the shift register when serial transfer is in progress. If the shift register was full before the serial transfer started, the RSPI leaves the status of the shift register unchanged, in the full state.
Irrespective of SPCMD0.CPHA bit setting, the timing at which the RSPI starts driving of the MISO output signal is the SSL0 signal assertion timing. The data which is output by the RSPI is either valid or invalid, depending on the SPCMD0.CPHA bit setting.
For details on the RSPI transfer format, see section 26.3.4, Transfer Format. The polarity of the SSL0 input signal depends on the setting of the SSL0P bit in the RSPI slave select polarity register (SSLP).

(2) Terminating a Serial Transfer

Irrespective of the SPCMD0.CPHA bit, the RSPI terminates the serial transfer after detecting an RSPCK edge corresponding to the final sampling timing. When free space is available in the receive buffer, upon termination of serial transfer the RSPI copies received data from the shift register to the receive buffer of the RSPI data register (SPDR). Upon termination of a serial transfer the RSPI changes the status of the shift register to "empty". A mode fault error occurs if the RSPI detects an SSL0 input signal negation from the beginning of serial transfer to the end of serial transfer (see section 26.3.8, Error Detection).
The final sampling timing changes depending on the bit length of transfer data. In slave mode, the RSPI data length depends on the SPCMD0.SPB[3:0] bit setting. The polarity of the SSL0 input signal depends on the SSLP.SSL0P bit setting.
For details on the RSPI transfer format, see section 26.3.4, Transfer Format.

(3) Notes on Single-Slave Operations

If the SPCMD0.CPHA bit is 0, the RSPI starts serial transfers when it detects the assertion edge for an SSL0 input signal. In the type of configuration shown in Figure 26.5 as an example, if the RSPI is used in single-slave mode, the SSL0 signal is always fixed at the active state. Therefore, when the SPCMD0.CPHA bit is set to 0, the RSPI cannot correctly start a serial transfer. To correctly execute transmit/receive operations by the RSPI in a configuration in which the SSL0 input signal is fixed at the active state, the SPCMD0.CPHA bit should be set to 1. If there is a need for setting the SPCMD0.CPHA bit to 0, the SSL0 input signal should not be fixed.

(4) Burst Transfer

If the SPCMD0.CPHA bit is 1, continuous serial transfer (burst transfer) can be executed while retaining the assertion state for the SSL0 input signal. If the SPCMD0.CPHA bit is 1, the period from the first RSPCK edge to the sampling timing for the reception of the final bit in an SSL0 signal active state corresponds to a serial transfer period. Even when the SSL0 input signal remains at the active level, the RSPI can accommodate burst transfers because it can detect the start of an access.
If the SPCMD0.CPHA bit is 0, second and subsequent serial transfers during burst transfer cannot be executed correctly.

(5) Initialization Flowchart

Figure 26.30 is a flowchart illustrating an example of initialization in SPI operation when the RSPI is used in slave mode. For a description of how to set up the interrupt controller, DTC, and input/output ports, see the descriptions given in the individual blocks.

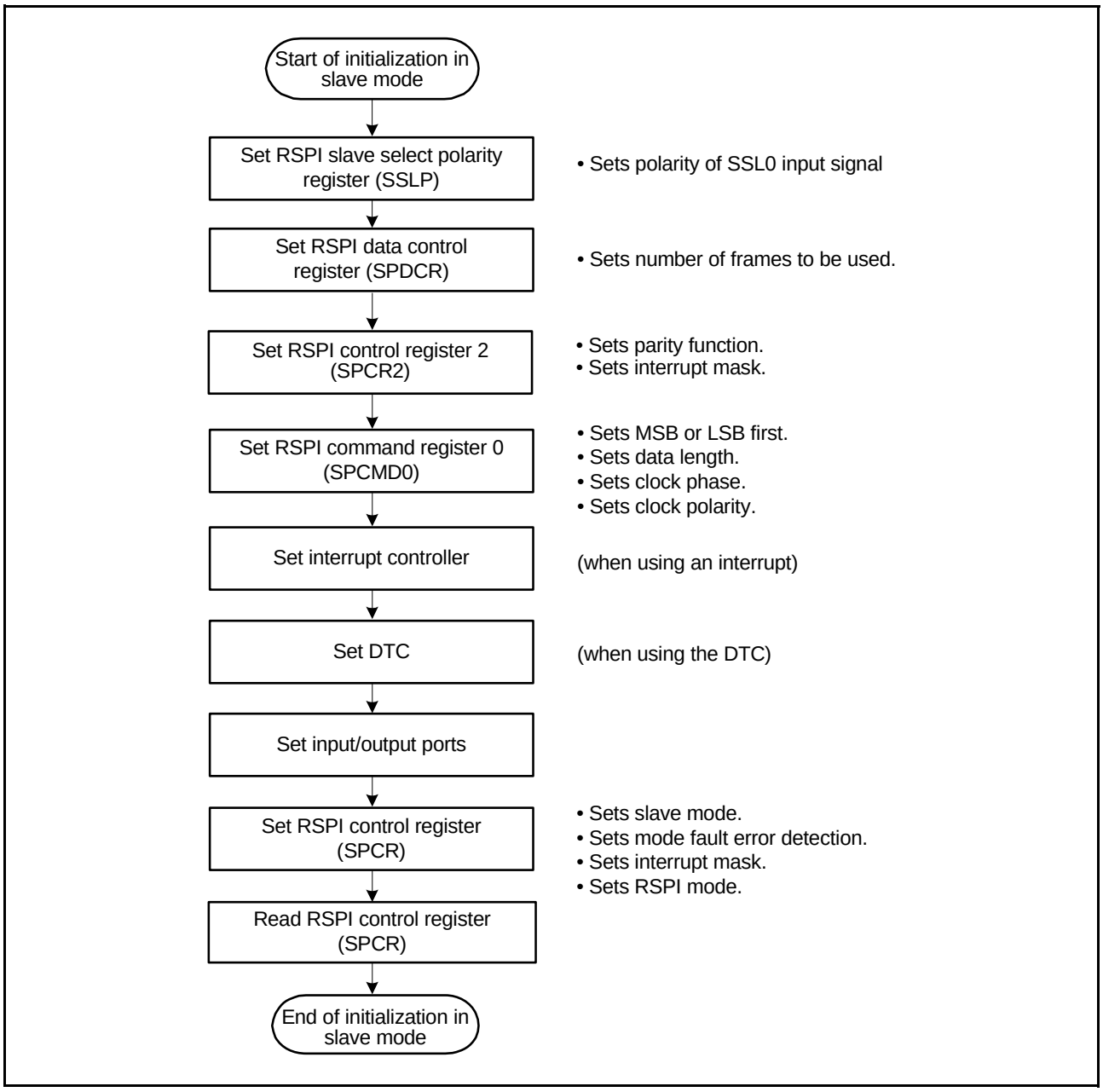


Figure 26.30 Example of Initialization Flowchart in Slave Mode (SPI Operation)

(6) Transfer Operation Flowchart (CPHA = 0)

Figure 26.31 is a flowchart illustrating a transfer in SPI operation when the RSPI is used in slave mode with the SPCMD0.CPHA bit set to 0.

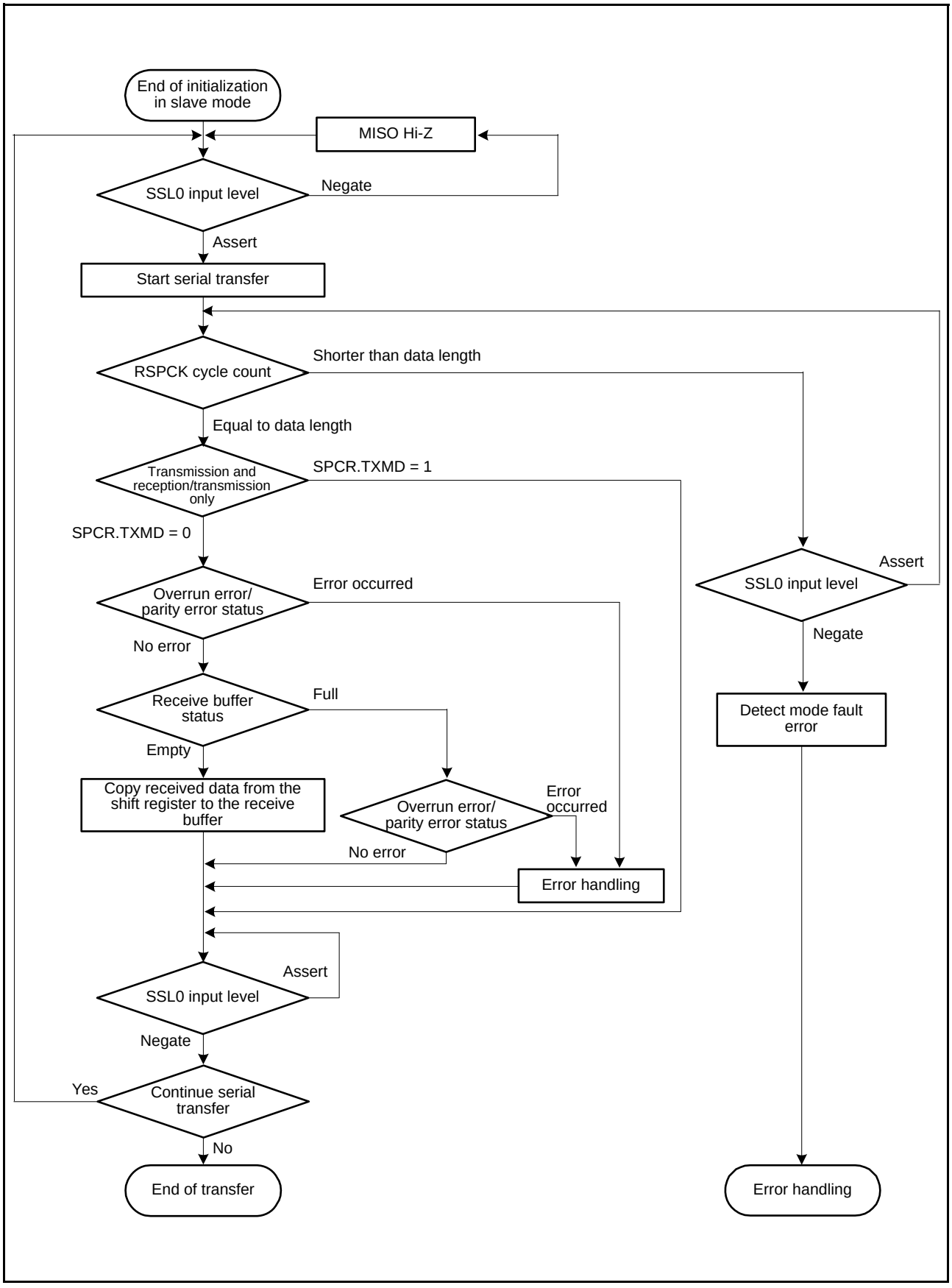


Figure 26.31 Transfer Operation Flowchart in Slave Mode (SPCMD0.CPHA = 0) (SPI Operation)

(7) Transfer Operation Flowchart (CPHA = 1)

Figure 26.32 is a flowchart illustrating a transfer in SPI operation when the RSPI is used in slave mode with both the SPCMD0.CPHA bit and SPCR.MODFEN bit set to 1. The subsequent operations are not guaranteed when the serial transfer is started with the MODFEN bit set to 0 and the SSL0 input level is negated with a number of RSPCK cycles shorter than the data length.

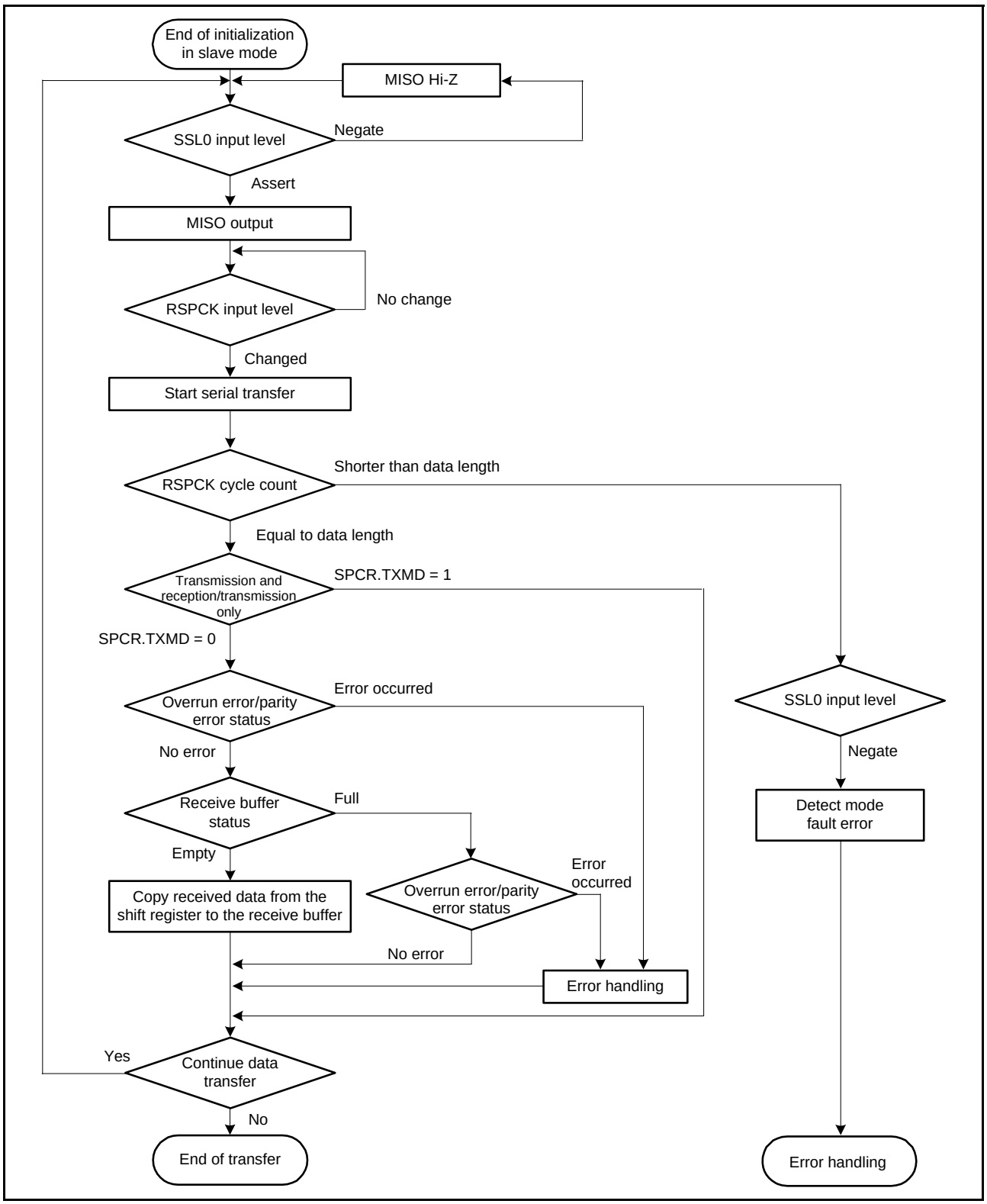


Figure 26.32 Transfer Operation Flowchart in Slave Mode (SPCMD0.CPHA = 1) (SPI Operation)

26.3.11 Clock Synchronous Operation

Setting the SPMS bit in the RSPI control register (SPCR) to 1 selects clock synchronous operation of the RSPI. In clock synchronous operation, the SSL pin is not used, and the three pins of RSPCK, MOSI, and MISO handle communications. The SSL pin is available as I/O port pins.
Although clock synchronous operation does not require use of the SSL pin, operation of the module is the same as in SPI operation. That is, in both master and slave operations, communications can be performed with the same flow as in SPI operation. However, mode fault errors are not detected because the SSL pin is not used.
Furthermore, operation is not guaranteed if clock synchronous operation proceeds when the SPCMD.CPHA bit (m = 0 to 7) is set to 0 in slave mode (SPCR.MSTR = 0).

26.3.11.1 Master Mode Operation

(1) Starting a Serial Transfer

The RSPI updates the data in the transmit buffer when data is written to the RSPI data register (SPDR) with the RSPI transmit buffer being empty (data for the next transfer is not set). If the shift register is empty due to the writing of 0 either after the writing to SPDR, the RSPI copies the data in the transmit buffer to the shift register and starts a serial transfer. Upon copying transmit data to the shift register, the RSPI changes the status of the shift register to "full", and upon termination of serial transfer, it changes the status of the shift register to "empty". The status of the shift register cannot be referenced from the CPU.
For details on the RSPI transfer format, see section 26.3.4, Transfer Format.

(2) Terminating a Serial Transfer

The RSPI terminates the serial transfer after transmitting an RSPCK edge corresponding to the sampling timing. If free space is available in the receive buffer, upon termination of serial transfer, the RSPI copies data from the shift register to the receive buffer of the RSPI data register (SPDR).
It should be noted that the final sampling timing varies depending on the bit length of transfer data. In master mode, the RSPI data length depends on the SPCMDm.SPB[3:0] bit (m = 0 to 7) setting.
For details on the RSPI transfer format, see section 26.3.4, Transfer Format.

(3) Sequence Control

The transfer format employed in master mode is determined by SPSCR, SPCMDm, SPBR, SPCKD, SSLND, and SPND. Although the SSL signals are not output in clock synchronous operation, these settings are valid.
SPSCR is a register used to determine the sequence configuration for serial transfers that are executed by the RSPI in master mode. The following items are set in RSPI command registers SPCMDm: SSL output signal value, MSB/LSB first, data length, some of the bit rate settings, RSPCK polarity/phase, whether SPCKD is to be referenced, whether SSLND is to be referenced, and whether SPND is to be referenced. SPBR holds some of the bit rate settings; SPCKD, an RSPI clock delay value; SSLND, an SSL negation delay; and SPND, a next-access delay value.
According to the sequence length that is assigned to SPSCR, the RSPI makes up a sequence comprised of a part or all of SPCMDm. The RSPI contains a pointer to the SPCMD that makes up the sequence. The CPU can check the value of this pointer by reading the SPSSR.SPCP[2:0] bits. When the SPCR.SPE bit is set to 1 and the RSPI function is enabled, the RSPI loads the pointer to the commands in SPCMD0, and incorporates the SPCMD0 settings into the transfer format at the beginning of serial transfer. The RSPI increments the pointer each time the next-access delay period for a data transfer ends. Upon completion of the serial transfer that corresponds to the final command comprising the sequence, the RSPI sets the pointer in SPCMD0, and in this manner the sequence is executed repeatedly.

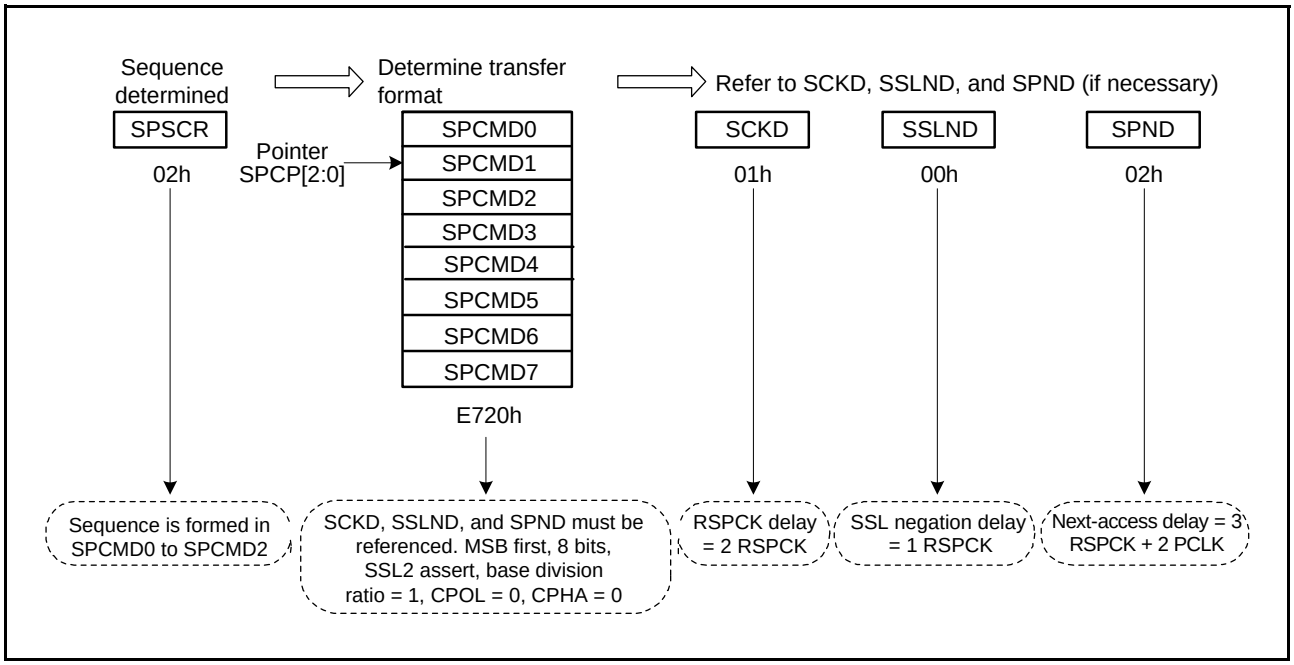


Figure 26.33 Determination Procedure of Serial Transfer Mode in Master Mode (Clock Synchronous Operation)

(4) Initialization Flowchart

Figure 26.34 is a flowchart illustrating an example of initialization in clock synchronous operation when the RSPI is used in master mode. For a description of how to set up the interrupt controller, DTC, and input/output ports, see the descriptions given in the individual blocks.

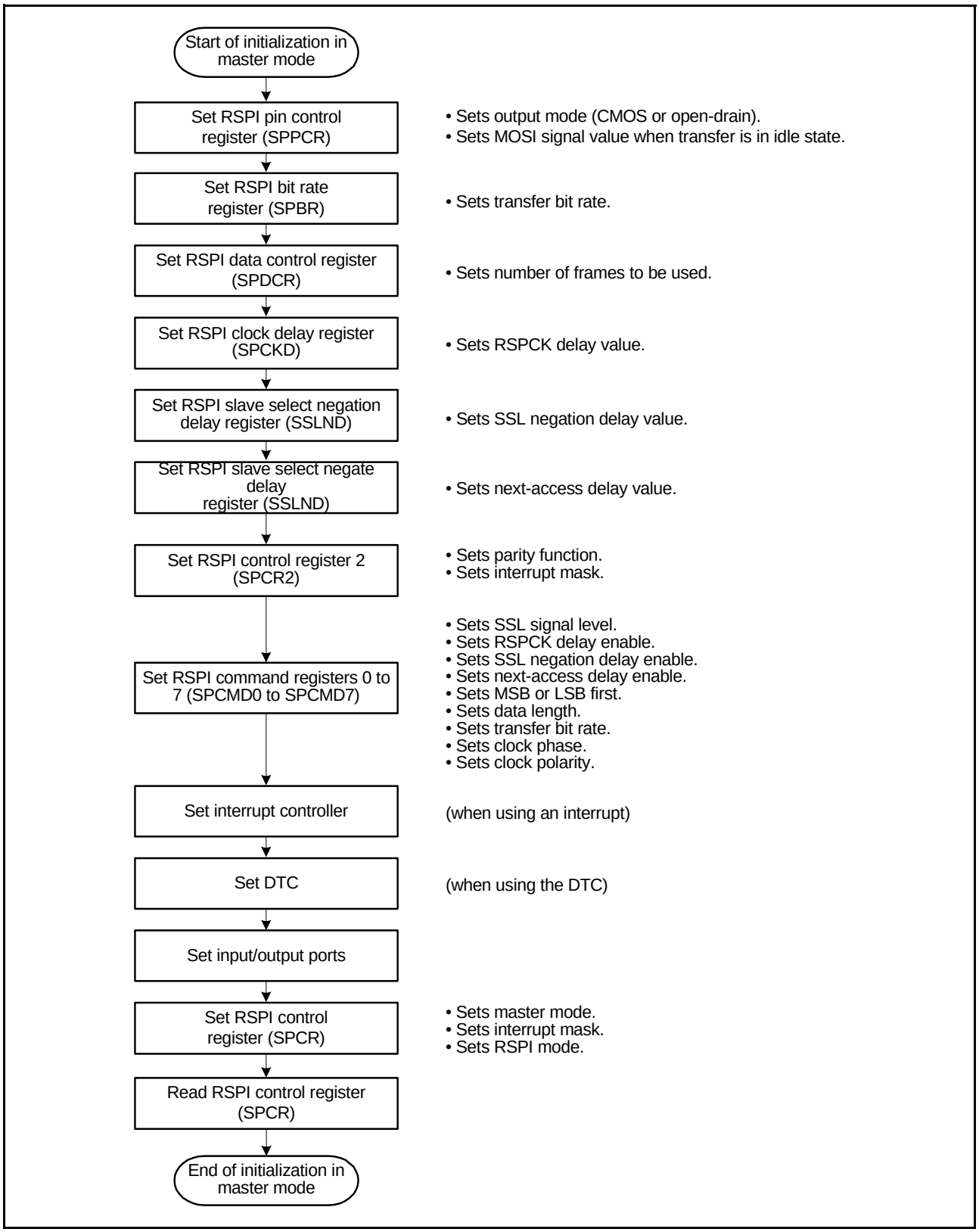


Figure 26.34 Example of Initialization Flowchart in Master Mode (Clock Synchronous Operation)

(5) Transfer Operation Flowchart

Figure 26.35 is a flowchart illustrating a transfer in clock synchronous operation when the RSPI is used in master mode.

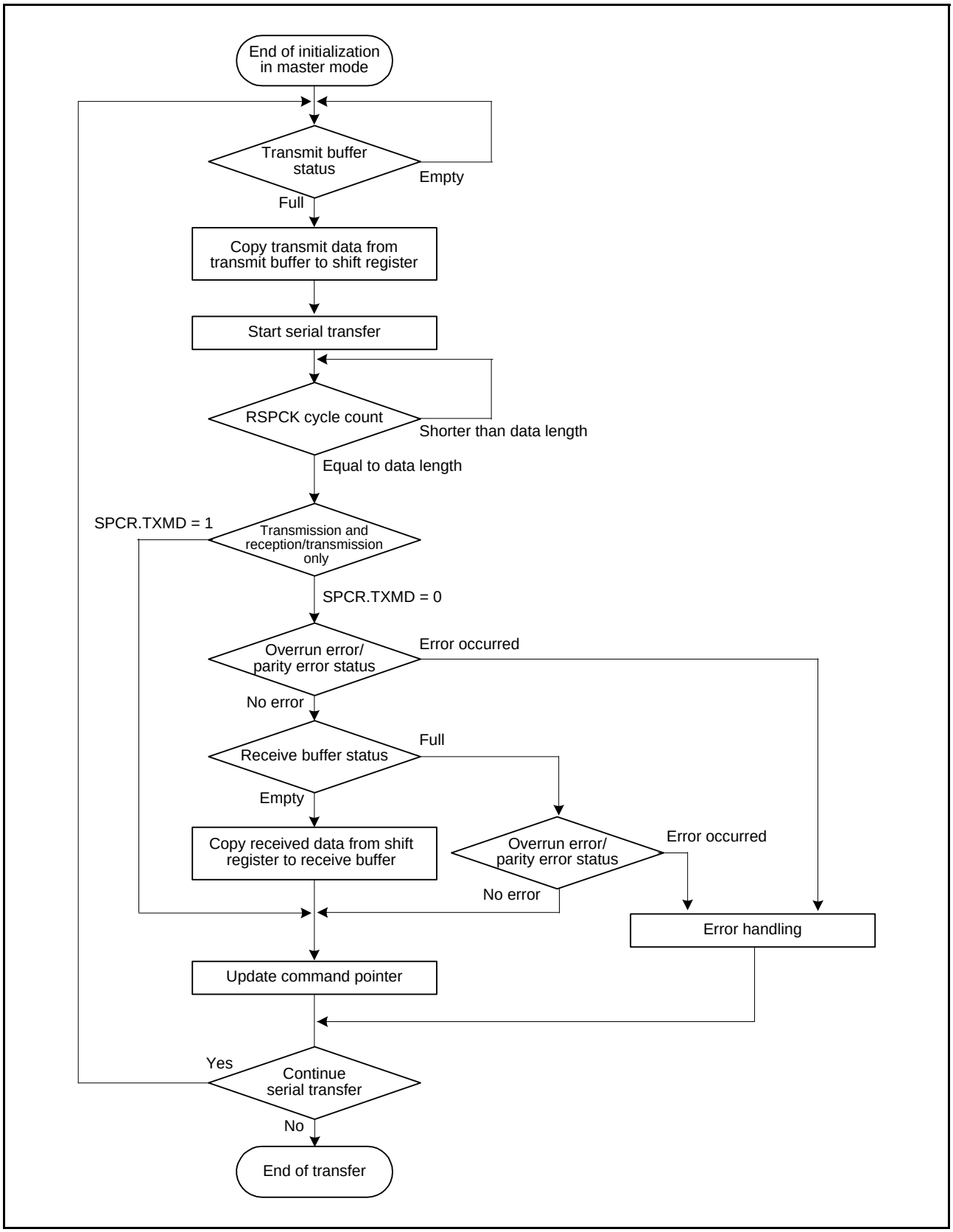


Figure 26.35 Transfer Operation Flowchart in Master Mode (Clock Synchronous Operation)

26.3.11.2 Slave Mode Operation

(1) Starting a Serial Transfer

When the SPCR.SPMS bit is 1, the first RSPCK edge triggers the start of a serial transfer in the RSPI.
When detecting the start of a serial transfer in a condition in which the shift register is empty, the RSPI changes the status of the shift register to "full", so that data cannot be copied from the transmit buffer to the shift register when serial transfer is in progress. If the shift register was full before the serial transfer started, the RSPI keeps the status of the shift register unchanged, in the full state.
When the SPCR.SPMS bit is 1, the RSPI always drives the MISO output signal.
For details on the RSPI transfer format, see section 26.3.4, Transfer Format. It should be noted that the SSL0 input signal is not used in clock synchronous operation.

(2) Terminating a Serial Transfer

The RSPI terminates the serial transfer after detecting an RSPCK edge corresponding to the final sampling timing. When free space is available in the receive buffer, upon termination of serial transfer the RSPI copies received data from the shift register to the receive buffer of the RSPI data register (SPDR). Upon termination of a serial transfer the RSPI changes the status of the shift register to "empty". The final sampling timing changes depending on the bit length of transfer data. In slave mode, the RSPI data length depends on the SPCMD0.SPB[3:0] bit setting.
For details on the RSPI transfer format, see section 26.3.4, Transfer Format.

(3) Initialization Flowchart

Figure 26.36 is a flowchart illustrating an example of initialization in clock synchronous operation when the RSPI is used in slave mode. For a description of how to set up the interrupt controller, DTC, and input/output ports, see the descriptions given in the individual blocks.

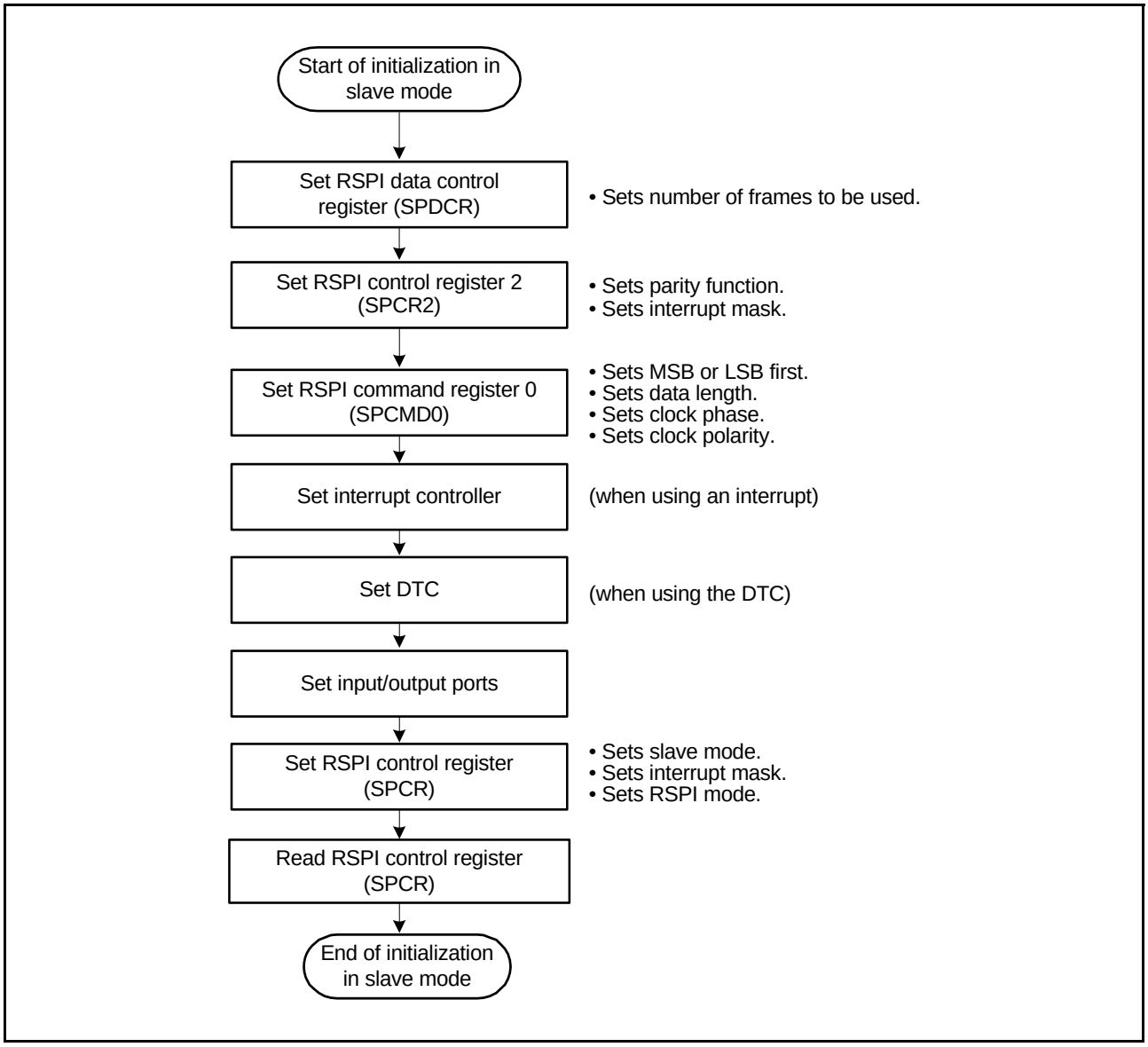


Figure 26.36 Example of Initialization Flowchart in Slave Mode (Clock Synchronous Operation)

(4) Transfer Operation Flowcharts

Figure 26.37 is a flowchart illustrating a transfer when the RSPI is in clock synchronous operation.

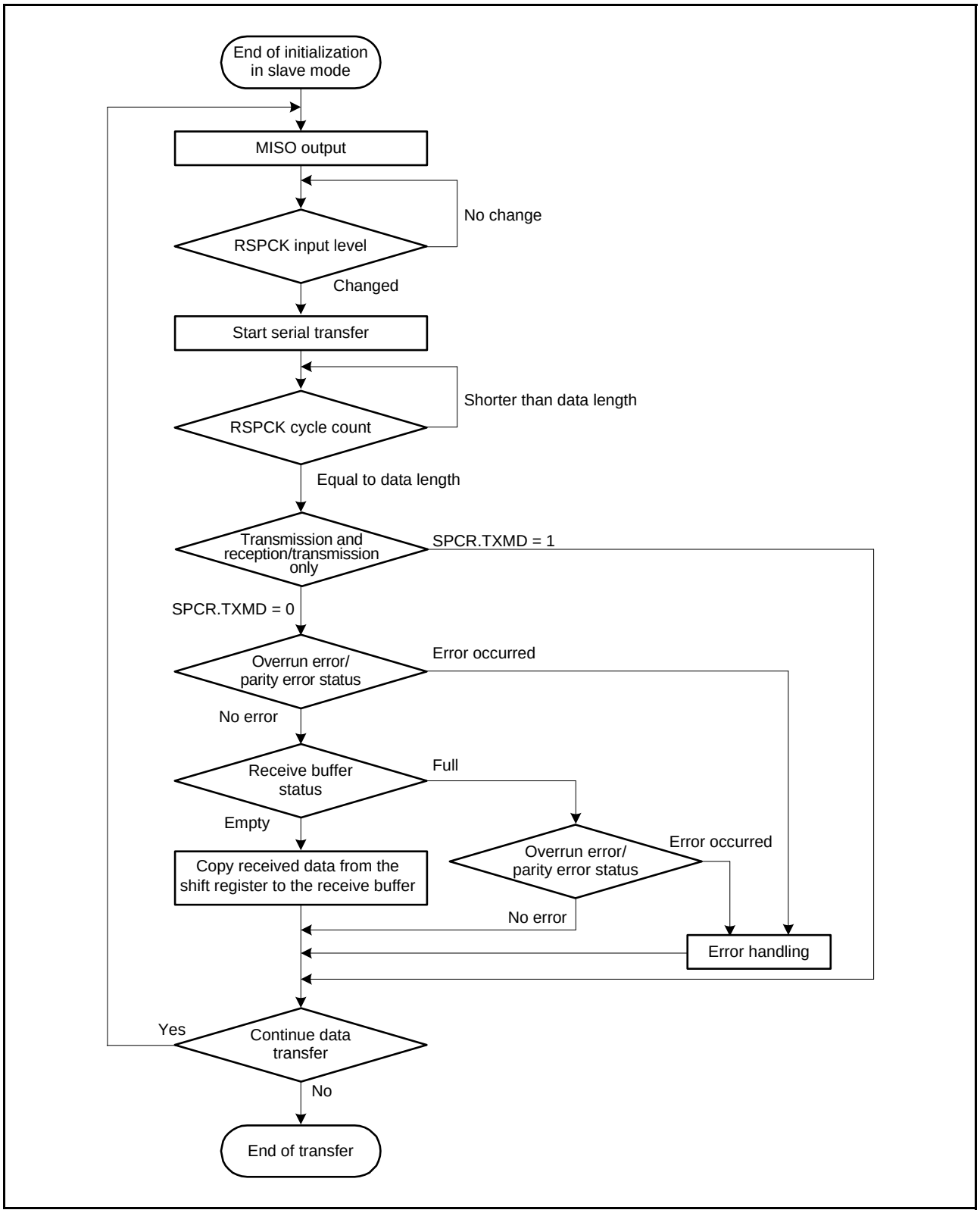


Figure 26.37 Transfer Operation Flowchart in Slave Mode (SPCMDm.CPHA = 1) (Clock Synchronous Operation)

26.3.12 Error Handling

Figure 26.38 to Figure 26.40 show error handling for the RSPI. The following error handling is used to return from the error state after an error has occurred in master mode or slave mode.

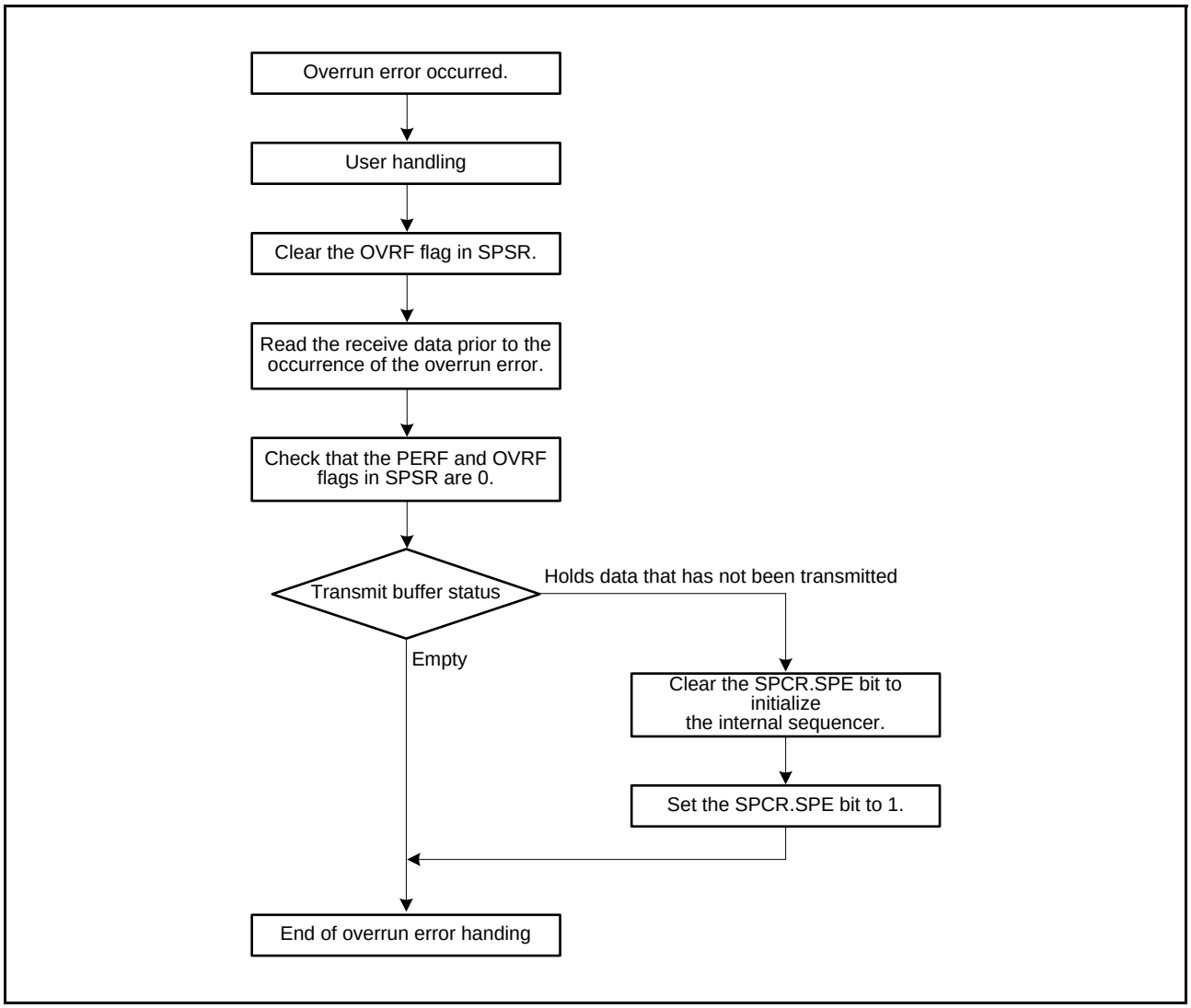


Figure 26.38 Error Handling (Overrun Error)

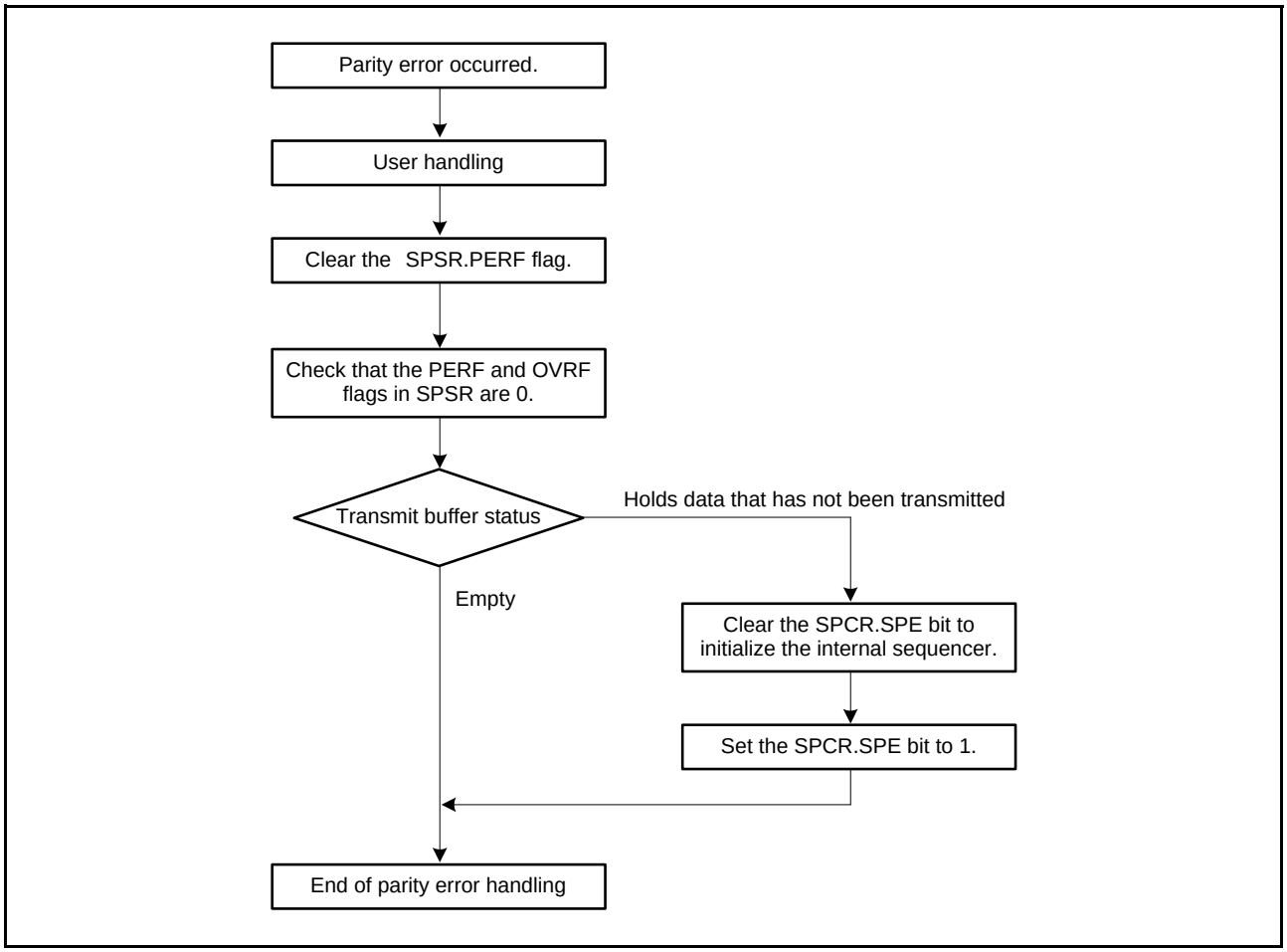


Figure 26.39 Error Handling (Parity Error)

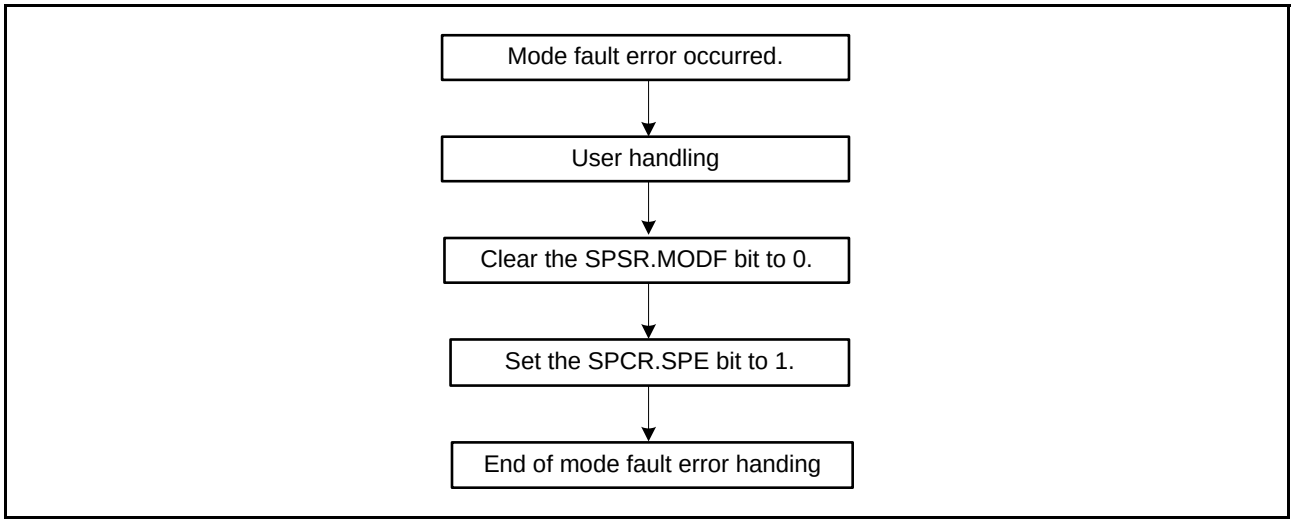


Figure 26.40 Error Handling (Mode Fault Error)

26.3.13 Loopback Mode

When the CPU writes 1 to the SPPCR.SPLP2 bit or SPPCR.SPLP bit in loopback mode, the RSPI shuts off the path between the MISO pin and the shift register if the SPCR.MSTR bit is 1, and between the MOSI pin and the shift register if the SPCR.MSTR bit is 0, and connects the input path and output path of the shift register. The RSPI does not shut off the path between the MOSI pin and the shift register if the SPCR.MSTR bit is 1, and between the MISO pin and the shift register if the SPCR.MSTR bit is 0.

When a serial transfer is executed in loopback mode, the transmit data for the RSPI becomes the received data for the RSPI.

Table 26.13 shows the relationship among the SPLP2 and SPLP bits in SPPCR and the received data. Figure 26.41 shows the configuration of the shift register input/output paths for the case where the RSPI in master mode is set in loopback mode (SPPCR.SPLP2 = 0, SPPCR.SPLP = 1).

Table 26.13 SPPCR.SPLP2 and SPLP Bit Settings and Received Data

SPPCR.SPLP2 Bit	SPPCR.SPLP Bit	Received Data
0	0	Input data from the MOSIn pin or MISOn pin (n = A, B)
0	1	Reversed transmit data
1	0	Transmit data
1	1	Transmit data

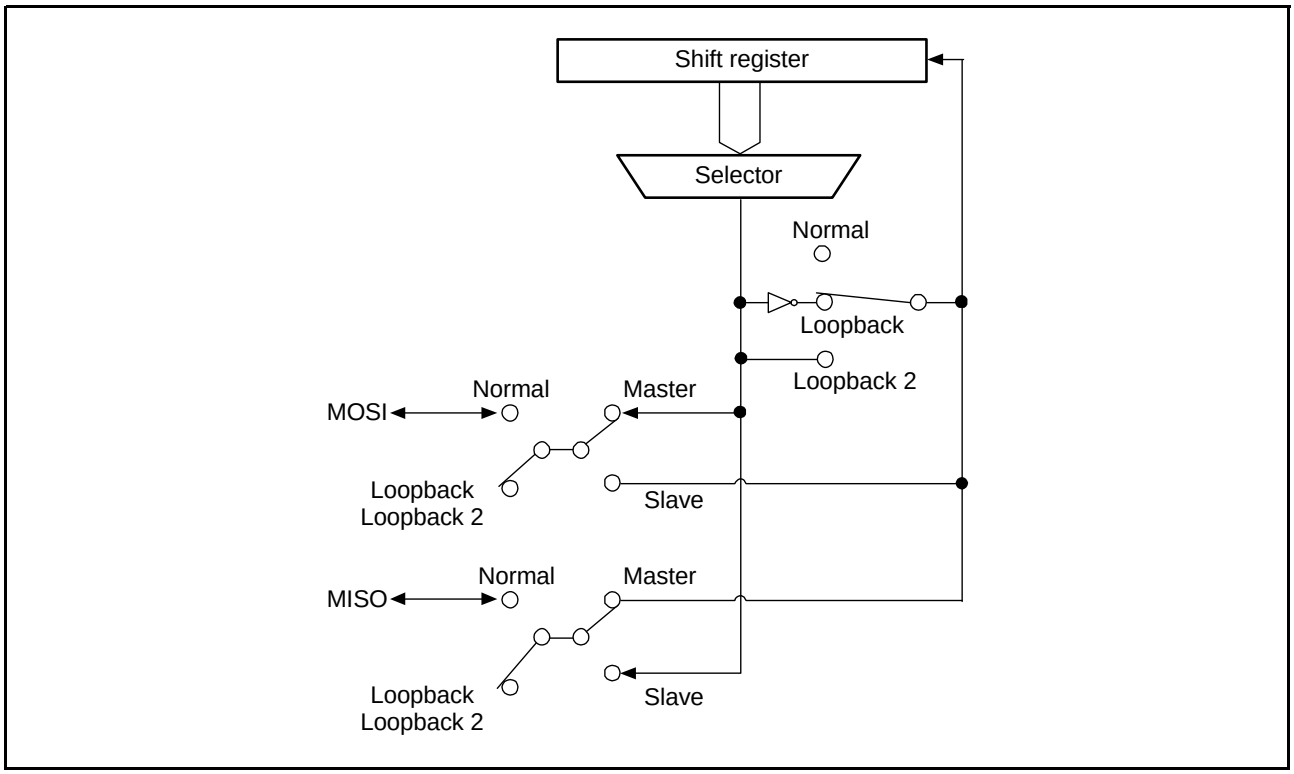


Figure 26.41 Configuration of Shift Register Input/Output Paths in Loopback Mode (Master Mode)

26.3.14 Self-Diagnosis of Parity Bit Function

The parity circuit consists of a parity bit adding unit used for transmit data and an error detecting unit used for received data. In order to detect defects in the parity bit adding unit and error detecting unit of the parity circuit, self-diagnosis is executed for the parity circuit following the flowchart shown in Figure 26.42.

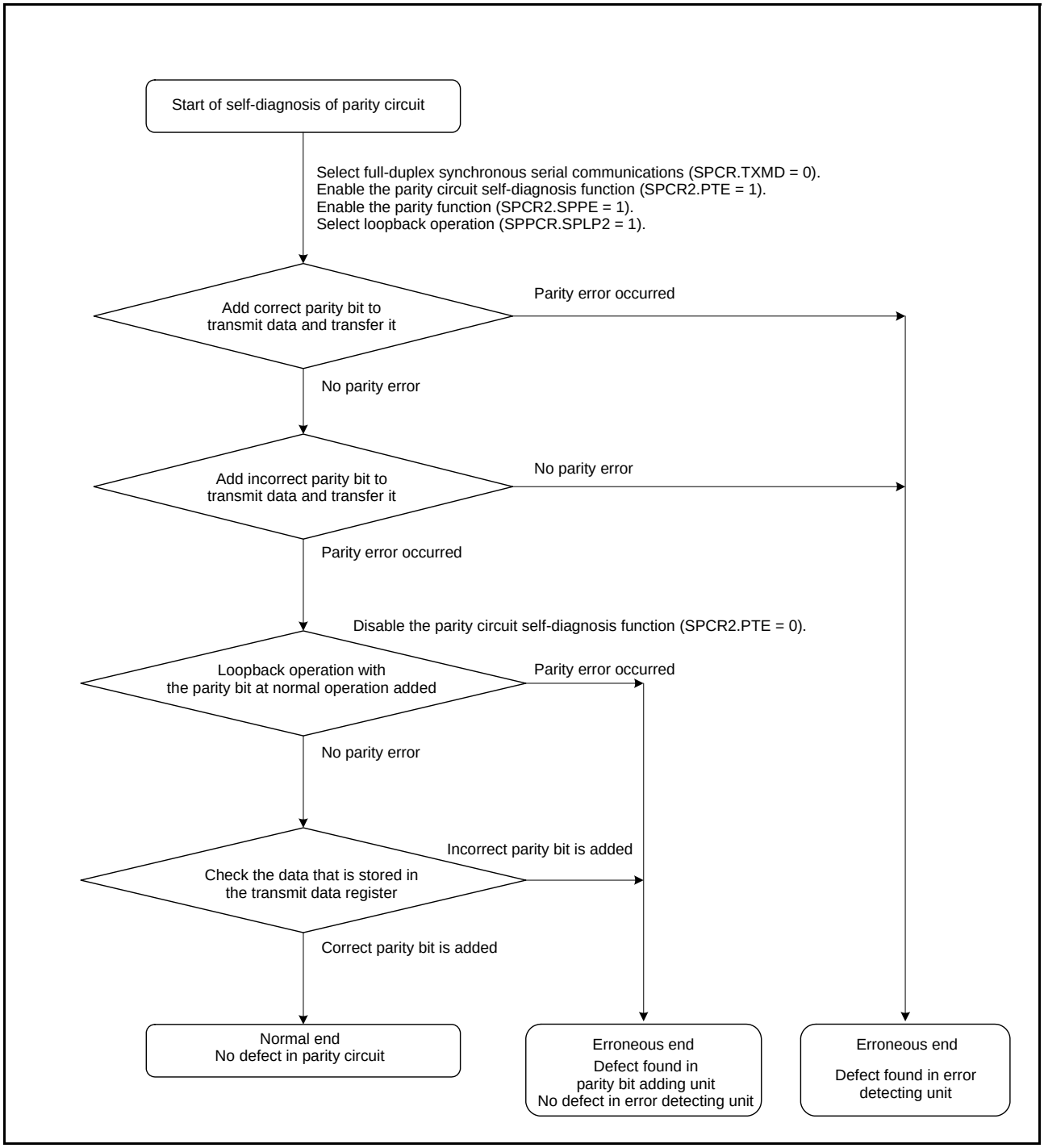


Figure 26.42 Flowchart for Self-Diagnosis of Parity Circuit

26.3.15 Interrupt Sources

The RSPI has interrupt sources of receive buffer full, transmit buffer empty, mode fault, and RSPI idle. In addition, the DTC can be activated by the receive buffer full or transmit buffer empty interrupt to perform data transfer.
Table 26.14 shows the RSPI interrupt sources. When any of the interrupt conditions in Table 26.14 is met, an interrupt is generated. Clear the interrupt sources by data transfer.
When using the DTC to perform data transmission/reception, the DTC must be set up first to be in a status in which transfer is enabled before making the RSPI settings. For the method for setting the DTC, refer to section 14, Data Transfer Controller (DTC).

Table 26.14 Interrupt Sources of RSPI

Interrupt Source	Abbreviation	Interrupt Condition	DTC Activation
Receive buffer full	SPRI0	(sprie = 1) • (Receive buffer full)	O
Transmit buffer empty	SPTI0	(sptie = 1) • (Transmit buffer empty)	O
Mode fault Overrun Parity error	SPEI0	(speie = 1) • {(modf = 1) | (ovrf = 1) | (perf = 1)}	—
RSPI idle	SPII0	(spiie = 1) • (idlnf = 0)	—

26.4 Usage Note

26.4.1 Transmit Operation when Parity Function is Enabled in Master Mode

To perform transmit operation with the parity bit added when the parity function is enabled in master mode, the following settings of each command register should be set to the same value.

- Transfer bit length setting of each command register
- MSB-first/LSB-first setting of each command register

27. LIN Module (LIN)

27.1 Overview

The LIN module is a hardware LIN communication controller that is compliant with LIN Specification Package Revisions 1.3, 2.0, and 2.1, and it transmits and receives frames, and judges errors automatically. The LIN module incorporates a 1-channel master controller.

Table 27.1 lists the specifications for the LIN module, and Figure 27.1 shows a block diagram of the LIN module.

Table 27.1 Specifications of LIN Module

Item	Specifications
Protocol	LIN Specification Package Revisions 1.3, 2.0, and 2.1
Number of channels	1 channel (LIN master)
Variable frame configuration	• Transmit break width: 13 to 28 Tbits • Transmit break delimiter width: 1 to 4 Tbits • Interbyte space (header): 0 to 7 Tbits (space between Sync field and ID field)*1 • Response space: 0 to 7 Tbits*1 • Interbyte space: 0 to 3 Tbits (space between data bytes in response space) • Wake-up: 1 to 16 Tbits
Check sum	• Automatic calculation in both transmission and reception • Either classic check sum or enhanced check sum is selectable (changeable at each frame)
Data bytes in response field	Variable from 0 to 8 bytes
Frame transmission mode	• Mode in which a header and response are transmitted by a single transmit start request • Mode in which a header and response are transmitted by respective transmit start requests (frame separate mode)
Wake-up transmission/reception	Available in LIN wake-up mode • Wake-up transmission (1 to 16 Tbits) • Wake-up reception Input signal Low time counting
Status	• Frame/wake-up transmit completion • Header transmit completion • Frame/wake-up receive completion*2 • Data 1 receive completion • Error detection • Operating mode (LIN reset mode, LIN wake-up mode, LIN operation mode, or LIN self-test mode)
Error status	• Bit error • Check sum error • Frame timeout error • Physical bus error • Framing error
Baud rate	Selectable LIN-specified value generated by the baud rate generator
Test mode	Self-test mode for user evaluation
Interrupt function	• Frame/wake-up transmit completion • Frame/wake-up receive completion*2 • Error detection

Note 1. The interbyte space (header) has the same value as the response space since both spaces are set in the same register.
Note 2. Wake-up reception indicates the input signal Low time counting.

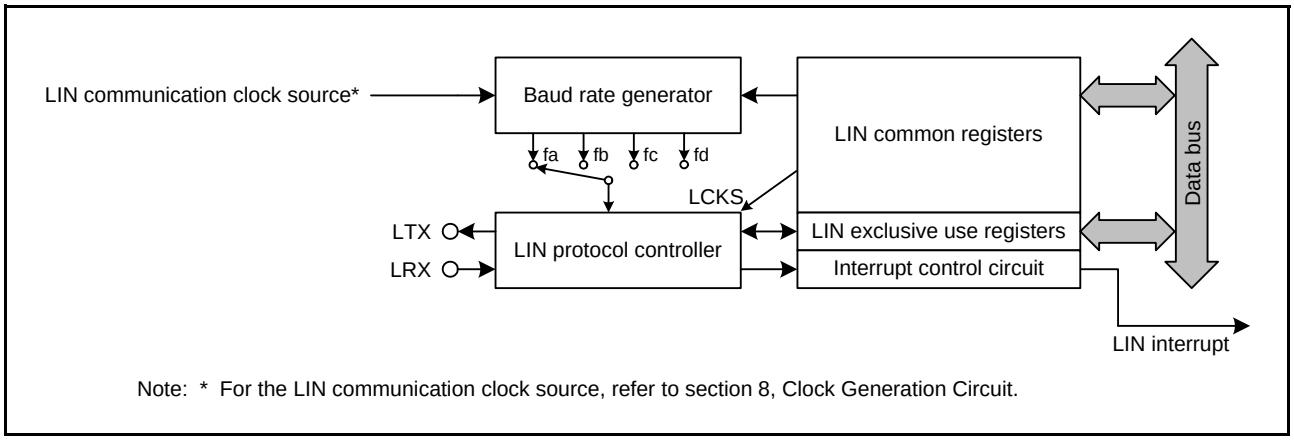


Figure 27.1 Block Diagram of LIN Module

- LTX and LRX: I/O pins of the LIN module
- Baud rate generator: Generates a communication clock for the LIN module
- LIN common registers: Common registers for the LIN module
- Interrupt control circuit: Controls the interrupt request (LIN interrupt) generated by the LIN module

Table 27.2 lists the I/O pins used in the LIN module.

Table 27.2 I/O Pins of LIN Module

Module Symbol	Pin Name	I/O	Description
LIN0	LRX	Input	Input pin for the LIN communication function
	LTX	Output	Output pin for the LIN communication function

27.2 Register Descriptions

Table 27.3 shows the registers of the LIN module.

Table 27.3 Registers of LIN Module

Module Symbol	Register Name	Symbol	Value after Reset	Address	Access Size
LIN0	LIN wake-up baud rate select register	LWBR	00h	0009 4001h	8
	LIN baud rate prescaler 0 register	LBRP0	00h	0009 4002h	8, 16
	LIN baud rate prescaler 1 register	LBRP1	00h	0009 4003h	8, 16
	LIN self-test control register	LSTC	00h	0009 4004h	8
	Mode register	L0MD	00h	0009 4008h	8, 16, 32
	Break field setting register	L0BRK	00h	0009 4009h	8, 16, 32
	Space setting register	L0SPC	00h	0009 400Ah	8, 16, 32
	Wake-up setting register	L0WUP	00h	0009 400Bh	8, 16, 32
	Interrupt enable register	L0IE	00h	0009 400Ch	8, 16
	Error detection enable register	L0EDE	00h	0009 400Dh	8, 16
	Control register	L0C	00h	0009 400Eh	8
	Transmission control register	L0TC	00h	0009 4010h	8, 16, 32
	Mode status register	L0MST	00h	0009 4011h	8, 16, 32
	Status register	L0ST	00h	0009 4012h	8, 16, 32
	Error status register	L0EST	00h	0009 4013h	8, 16, 32
	Response field set register	L0RFC	00h	0009 4014h	8, 16
	Buffer register	L0IDB	Undefined	0009 4015h	8, 16
	Check sum buffer register	L0CBR	Undefined	0009 4016h	8
	Data 1 buffer register	L0DB1	Undefined	0009 4018h	8, 16, 32
	Data 2 buffer register	L0DB2	Undefined	0009 4019h	8, 16, 32
	Data 3 buffer register	L0DB3	Undefined	0009 401Ah	8, 16, 32
	Data 4 buffer register	L0DB4	Undefined	0009 401Bh	8, 16, 32
	Data 5 buffer register	L0DB5	Undefined	0009 401Ch	8, 16, 32
	Data 6 buffer register	L0DB6	Undefined	0009 401Dh	8, 16, 32
	Data 7 buffer register	L0DB7	Undefined	0009 401Eh	8, 16, 32
	Data 8 buffer register	L0DB8	Undefined	0009 401Fh	8, 16, 32

27.2.1 LIN Wake-Up Baud Rate Select Register (LWBR)

Address: 0009 4001h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	LWBR0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	LWBR0	Wake-up Baud Rate Select	0: When LIN1.3 is used 1: When LIN2.0 and 2.1 are used	R/W
b7 to b1	—	Reserved	These bits are read as 0. The write value should be 0.	R/W

LWBR register should be set in LIN reset mode.

LWBR0 Bit (Wake-up Baud Rate Select)

When LIN Specification Package Revision 1.3 is used, set the LWBR.LWBR0 bit to 0. This allows the input signal Low time to be measured for 2.5 or more Tbits of fLIN. When LIN Specification Package Revisions 2.0 and 2.1 are used, set the LWBR.LWBR0 bit to 1. This allows the input signal Low time to be measured for 130 μs or more.

27.2.2 LIN Baud Rate Prescaler 0 Register (LBRP0)

Address: 0009 4002h

	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Description	Setting Range	R/W
b7 to b0	The peripheral clock is divided by (N + 1) by the baud rate prescaler. (N = setting of 0 to 255)	00h to FFh	R/W

LBRP0 register should be set in LIN reset mode.

27.2.3 LIN Baud Rate Prescaler 1 Register (LBRP1)

Address: 0009 4003h

	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Description	Setting Range	R/W
b7 to b0	The peripheral clock is divided by (M + 1) by the baud rate prescaler. (M = setting of 0 to 255)	00h to FFh	R/W

LBRP1 register should be set in LIN reset mode.

27.2.4 LIN Self-Test Control Register (LSTC)

Address: 0009 4004h

	b7	b6	b5	b4	b3	b2	b1	b0
								LSTM
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b7 to b1	When A7h, 58h, and 01h are consecutively written, the LIN module enters LIN self-test mode.			R/W
b0	LSTM	Self-Test Mode	0: Non-LIN self-test mode 1: LIN self-test mode	R/W

LSTC register should be set in LIN reset mode.
LSTC register is used to unlock protection of LIN self-test mode.
When A7h, 58h, and 01h are consecutively written to this register, the LIN module enters LIN self-test mode.
If consecutive writing is successful and the LIN module has entered LIN self-test mode, the LSTM bit is set to 1. Do not perform another writing while consecutive writing is in progress.
For details of transition to LIN self-test mode, refer to section 27.12.1, Entry into LIN Self-Test Mode.

LSTM Bit (Self-Test Mode)

This bit is set to 1 when the LIN module enters LIN self-test mode.
For details of how to exit LIN self-test mode, refer to section 27.12.1, Entry into LIN Self-Test Mode.
Other than consecutively writing A7h, 58h, and 01h to this register, writing 1 does not change the value of this bit.

27.2.5 Mode Register (L0MD)

Address: 0009 4008h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	LCKS[1:0]		—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1, b0	—	Reserved	These bits are read as 0. The write value should be 0.	R/W
b3, b2	LCKS[1:0]	LIN System Clock Select	b3 b2 0 0 : fa (clock generated by baud rate prescaler 0) 0 1 : fb (clock generated by baud rate prescaler 0 is divided by 2) 1 0 : fc (clock generated by baud rate prescaler 0 is divided by 8) 1 1 : fd (clock generated by baud rate prescaler 1 is divided by 2)	R/W
b7 to b4	—	Reserved	These bits are read as 0. The write value should be 0.	R/W

L0MD register should be set in LIN reset mode.

LCKS[1:0] Bits (LIN System Clock Select)

These bits select the clock to be input to the protocol controller.

When these bits are set to 00b, fa (clock generated by baud rate prescaler 0) is input to the protocol controller.

When these bits are to 01b, fb (clock generated by baud rate prescaler 0 is divided by 2) is input to the protocol controller.

When these bits are to 10b, fc (clock generated by baud rate prescaler 0 is divided by 8) is input to the protocol controller.

When these bits are to 11b, fd (clock generated by baud rate prescaler 1 is divided by 2) is input to the protocol controller.

27.2.6 Break Field Setting Register (L0BRK)

Address: 0009 4009h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	BDT[1:0]		BLT[3:0]			
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b3 to b0	BLT[3:0]	Transmit Break (Low) Width Setting	b3 b0 0 0 0 0: 13 Tbits 0 0 0 1: 14 Tbits 0 0 1 0: 15 Tbits : 1 1 1 0: 27 Tbits 1 1 1 1: 28 Tbits	R/W
b5, b4	BDT[1:0]	Transmit Break Delimiter (High) Width Setting	b5 b4 0 0 : 1 Tbit 0 1 : 2 Tbits 1 0 : 3 Tbits 1 1 : 4 Tbits	R/W
b7, b6	—	Reserved	These bits are read as 0. The write value should be 0.	R/W

L0BRK register should be set in LIN reset mode.
The length of one frame may exceed the frame timeout period depending on the combination of settings. Make sure to set appropriate values.

BLT[3:0] Bits (Transmit Break (Low) Width Setting)

These bits set the (Low) time pulse width for a break in the transmit frame header.
A value from 13 Tbits to 28 Tbits can be set.

BDT[1:0] Bits (Transmit Break Delimiter (High) Width Setting)

These bits set the (High) time pulse width for a break delimiter in the transmit frame header.
A value from 1 Tbit to 4 Tbits can be set.

27.2.7 Space Setting Register (L0SPC)

Address: 0009 400Ah

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	IBS[1:0]		—	IBSH[2:0]		
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b2 to b0	IBSH[2:0]	Interbyte Space (Header)/ Response Space Setting	b2 b0 0 0 0 : 0 Tbit 0 0 1 : 1 Tbit 0 1 0 : 2 Tbits 0 1 1 : 3 Tbits 1 0 0 : 4 Tbits 1 0 1 : 5 Tbits 1 1 0 : 6 Tbits 1 1 1 : 7 Tbits	R/W
b3	—	Reserved	This bit is read as 0. The write value should be 0.	R/W
b5, b4	IBS[1:0]	Interbyte Space Setting	b5 b4 0 0 : 0 Tbit 0 1 : 1 Tbit 1 1 : 2 Tbits 1 1 : 3 Tbits	R/W
b7, b6	—	Reserved	These bits are read as 0. The write value should be 0.	R/W

L0SPC register should be set in LIN reset mode.
This register is enabled only for transmission (header and response). In response reception, this register is disabled.
The length of one frame may exceed the frame timeout period depending on the combination of settings. Make sure to set appropriate values.

IBSH[2:0] Bits (Interbyte Space (Header)/Response Space Setting)

These bits set the width of the interbyte space (header) and response space required for the transmit frame header.
A value from 0 Tbit to 7 Tbits can be set.
The values of the interbyte space (header) and response space are the same.

IBS[1:0] Bits (Interbyte Space Setting)

These bits set the width of the interbyte space required for the transmit frame response.
A value from 0 Tbit to 3 Tbits can be set.

27.2.8 Wake-Up Setting Register (L0WUP)

Address: 0009 400Bh

	b7	b6	b5	b4	b3	b2	b1	b0
	WUTL[3:0]				—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b3 to b0	—	Reserved	These bits are read as 0. The write value should be 0.	R/W
b7 to b4	WUTL[3:0]	Wake-up Transmission Low Width Setting	b7 b4 0 0 0 0 : 1 Tbit 0 0 0 1 : 2 Tbits 0 0 1 0 : 3 Tbits 0 0 1 1 : 4 Tbits : 1 1 0 0 : 13 Tbits 1 1 0 1 : 14 Tbits 1 1 1 0 : 15 Tbits 1 1 1 1 : 16 Tbits	R/W

L0WUP register should be set in LIN reset mode.

WUTL[3:0] Bits (Wake-up Transmission Low Width Setting)

These bits set the Low time pulse width of wake-up transmission.
A value from 1 Tbit to 16 Tbits can be set.

27.2.9 Interrupt Enable Register (L0IE)

Address: 0009 400Ch

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	ERRIE	FRCIE	FTCIE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	FTCIE	Frame/Wake-up Transmit Completion Interrupt Enable	0: Frame/wake-up transmit completion interrupt is disabled 1: Frame/wake-up transmit completion interrupt is enabled	R/W
b1	FRCIE	Frame/Wake-up Receive Completion Interrupt Enable	0: Frame/wake-up receive completion interrupt is disabled 1: Frame/wake-up receive completion interrupt is enabled	R/W
b2	ERRIE	Error Detection Interrupt Enable	0: Error detection interrupt is disabled 1: Error detection interrupt is enabled	R/W
b7 to b3	—	Reserved	These bits are read as 0. The write value should be 0.	R/W

L0IE register should be set in LIN reset mode.

FTCIE Bit (Frame/Wake-up Transmit Completion Interrupt Enable)

This bit enables or disables an interrupt when a frame or wake-up frame transmission is completed.
When this bit is set to 0, a LIN interrupt is not generated when the L0ST.FTC flag becomes 1.
When this bit is set to 1, a LIN interrupt is generated when the L0ST.FTC flag becomes 1.

FRCIE Bit (Frame/Wake-up Receive Completion Interrupt Enable)

This bit enables or disables an interrupt when a frame or wake-up frame reception is completed.
When this bit is set to 0, a LIN interrupt is not generated when the L0ST.FRC flag becomes 1.
When this bit is set to 1, a LIN interrupt is generated when the L0ST.FRC flag becomes 1.

ERRIE Bit (Error Detection Interrupt Enable)

This bit enables or disables an interrupt when an error is detected.
When this bit is set to 0, a LIN interrupt is not generated when the L0ST.ERR flag becomes 1.
When this bit is set to 1, a LIN interrupt is generated when the L0ST.ERR flag becomes 1.
The sources to generate the LIN interrupt are the following interrupts: bit error, physical bus error, frame timeout error, framing error, and check sum error.
The detection of a bit error, physical bus error, frame timeout error, and framing error can be enabled or disabled by L0EDE.

27.2.10 Error Detection Enable Register (L0EDE)

Address: 0009 400Dh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	FERE	FTERE	PBERE	BERE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	BERE	Bit Error Detection Enable	0: Bit error detection is disabled 1: Bit error detection is enabled	R/W
b1	PBERE	Physical Bus Error Detection Enable	0: Physical bus error detection is disabled 1: Physical bus error detection is enabled	R/W
b2	FTERE	Frame Timeout Error Detection Enable	0: Frame timeout error detection is disabled 1: Frame timeout error detection is enabled	R/W
b3	FERE	Framing Error Detection Enable	0: Framing error detection is disabled 1: Framing error detection is enabled	R/W
b7 to b4	—	Reserved	These bits are read as 0. The write value should be 0.	R/W

L0EDE register should be set in LIN reset mode.

BERE Bit (Bit Error Detection Enable)

This bit enables or disables bit error detection.
When this bit is set to 0, no bit error is detected.
When this bit is set to 1, a bit error is detected.
The detection result when this bit is 1 is reflected in the L0EST.BER flag.
For details on a bit error, refer to section 27.10, Error Status.

PBERE Bit (Physical Bus Error Detection Enable)

This bit enables or disables physical bus error detection.
When this bit is set to 0, no physical bus error is detected.
When this bit is set to 1, a physical bus error is detected.
The detection result when this bit is 1 is reflected in the L0EST.PBER flag.
For details on a physical bus error, refer to section 27.10, Error Status.

FTERE Bit (Frame Timeout Error Detection Enable)

This bit enables or disables frame timeout error detection.
When this bit is set to 0, no frame timeout error is detected.
When this bit is set to 1, a frame timeout error is detected.
The detection result when this bit is 1 is reflected in the L0EST.FTER flag.
For details on a frame timeout error, refer to section 27.10, Error Status.

FERE Bit (Framing Error Detection Enable)

This bit enables or disables framing error detection.
When this bit is set to 0, no framing error is detected.
When this bit is set to 1, a framing error is detected.
The detection result when this bit is 1 is reflected in the L0EST.FER flag.
For details on a framing error, refer to section 27.10, Error Status.

27.2.11 Control Register (L0C)

Address: 0009 400Eh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	OM1	OM0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	OM0	LIN Reset	0: LIN reset mode 1: Non-LIN reset mode	R/W
b1	OM1	LIN Mode Select	0: LIN wake-up mode 1: LIN operation mode	R/W
b7 to b2	—	Reserved	These bits are read as 0. The write value should be 0.	R/W

When the LIN module exits LIN reset mode, this register should be set to 01h to enter LIN wake-up mode and 03h to enter LIN operation mode.
In LIN self-test mode, this register should be set to 03h after the LIN module enters LIN self-test mode.

OM0 Bit (LIN Reset)

This bit selects whether the LIN module enters or exits LIN reset mode.
When this bit is set to 0, the LIN module enters LIN reset mode.
When this bit is set to 1, the LIN module exits LIN reset mode.

OM1 Bit (LIN Mode Select)

This bit selects the LIN operating mode (LIN wake-up mode or LIN operation mode) when the LIN module exits LIN reset mode.
When this bit is set to 0, the LIN module enters LIN wake-up mode.
When this bit is set to 1, the LIN module enters LIN operation mode.
This register is enabled only when the L0MST.OMM0 bit is set to 1.
This bit cannot be written to while the L0TC.FTS bit is 1.

27.2.12 Transmission Control Register (L0TC)

Address: 0009 4010h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	RTS	FTS
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	FTS	Frame Transmission/Wake-up Transmission and Reception Start	0: Frame transmission/wake-up transmission and reception is stopped 1: Frame transmission/wake-up transmission and reception is started	R/W
b1	RTS	Response Transmission Start	0: Response transmission in frame separate mode is stopped 1: Response transmission in frame separate mode is started	R/W
b7 to b2	—	Reserved	These bits are read as 0. The write value should be 0.	R/W

FTS Bit (Frame Transmission/Wake-up Transmission and Reception Start)

Set this bit to 1 when a frame/wake-up transmission starts.

Set this bit to 1 to perform a wake-up reception (input signal Low time counting).

This bit is set to 1 during communication. It becomes 0 when there is no communication or when the LIN module enters LIN reset mode.

This bit can be set to 1 only. It cannot be set to 0. This bit automatically becomes 0 when the transmission is completed.

RTS Bit (Response Transmission Start)

Set this bit to 1 when a response transmission starts.

This bit is set to 1 during communication. It becomes 0 when there is no communication or when the LIN module enters LIN reset mode.

This bit can be set to 1 only. It cannot be set to 0. This bit automatically becomes 0 when the transmission is completed.

When setting the RTS bit to 1, use an MOV instruction to write 02h to the register.

Set this bit when the L0RFC.FSM bit is 1 (frame separate mode) and the FTS bit is 1 (frame transmission/wake-up transmission and reception started).

27.2.13 Mode Status Register (L0MST)

Address: 0009 4011h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	OMM1	OMM0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	OMM0	LIN0 Reset Status Monitor	0: LIN0 reset mode 1: Non-LIN0 reset mode	R
b1	OMM1	LIN0 Mode Status Monitor	0: LIN0 wake-up mode 1: LIN0 operation mode	R
b7 to b2	—	Reserved	These bits are read as 0. The write value should be 0.	R/W

OMM0 Bit (LIN0 Reset Status Monitor)

OMM1 Bit (LIN0 Mode Status Monitor)

These bits are used to check the current operating mode.

27.2.14 Status Register (L0ST)

Address: 0009 4012h

	b7	b6	b5	b4	b3	b2	b1	b0
	HTRC	D1RC	—	—	ERR	—	FRC	FTC
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	FTC	Frame/Wake-up Transmit Completion Flag	0: Transmission is uncompleted 1: Frame or wake-up transmission has been completed	R/W
b1	FRC	Frame/Wake-up Receive Completion Flag	0: Reception is uncompleted 1: Frame or wake-up reception has been completed	R/W
b2	—	Reserved	This bit is read as 0. The write value should be 0.	R/W
b3	ERR	Error Detection Flag	0: Error is not detected 1: Error has been detected	R
b5, b4	—	Reserved	These bits are read as 0. The write value should be 0.	R/W
b6	D1RC	Data 1 Receive Completion Flag	0: Reception is uncompleted 1: Data 1 reception has been completed	R/W
b7	HTRC	Header Transmit Completion Flag	0: Transmission is uncompleted 1: Header transmission has been completed	R/W

L0ST register automatically becomes 00h when the LIN module enters LIN reset mode or when the next communication starts.
This register retains 00h during LIN reset mode.
L0ST cannot be written to while the L0TC.FTS flag is 1 (frame transmission/wake-up transmission and reception started).

FTC Flag (Frame/Wake-up Transmit Completion Flag)

Only 0 can be written to this bit. When 1 is written to this bit, the value before the write is retained.
This bit becomes 1 when a frame or wake-up transmission is completed. An interrupt is generated if the L0IE.FTCIE bit is set to 1 (interrupt enabled) at this time. To set this bit to 0 before the next communication starts, write 0 to this bit in LIN operation mode.

FRC Flag (Frame/Wake-up Receive Completion Flag)

Only 0 can be written to this bit. When 1 is written to this bit, the value before the write is retained.
This bit becomes 1 when a frame or wake-up reception is completed. An interrupt is generated if the L0IE.FRCIE bit is set to 1 (interrupt enabled) at this time. To set this bit to 0 before the next communication starts, write 0 to this bit in LIN operation mode.

ERR Flag (Error Detection Flag)

This bit becomes 1 when an error is detected. An interrupt is generated if the L0IE.ERRIE bit is set to 1 (interrupt enabled) at this time. To set this bit to 0 before the next communication starts, write 0 to the L0EST.CSER, FER, FTER, PBER, and BER flags in LIN operation mode. This will make the ERR flag become 0.
D1RC Flag (Data 1 Receive Completion Flag)
Only 0 can be written to this bit. When 1 is written to this bit, the value before the write is retained.
This bit becomes 1 when a data 1 reception is completed, but no interrupt is generated. To set this bit to 0 before the next communication starts, write 0 to this bit in LIN operation mode.

HTRC Flag (Header Transmit Completion Flag)

Only 0 can be written to this bit. When 1 is written to this bit, the value before the write is retained.
This bit becomes 1 when a header reception is completed, but no interrupt is generated. To set this bit to 0 before the next communication starts, write 0 to this bit in LIN operation mode.

27.2.15 Error Status Register (L0EST)

Address: 0009 4013h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	CSER	—	FER	FTER	PBER	BER
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	BER	Bit Error Flag	0: Bit error is not detected 1: Bit error has been detected	R/W
b1	PBER	Physical Bus Error Flag	0: Physical bus error is not detected 1: Physical bus error has been detected	R/W
b2	FTER	Frame Timeout Error Flag	0: Frame timeout error is not detected 1: Frame timeout error has been detected	R/W
b3	FER	Framing Error Flag	0: Framing error is not detected 1: Framing error has been detected	R/W
b4	—	Reserved	This bit is read as 0. The write value should be 0.	R/W
b5	CSER	Check Sum Error Flag	0: Check sum error is not detected 1: Check sum error has been detected	R/W
b7, b6	—	Reserved	These bits are read as 0. The write value should be 0.	R/W

L0EST register automatically becomes 00h when the LIN module enters LIN reset mode or when the next communication starts.
This register retains 00h during LIN reset mode.
L0EST cannot be written to while the L0TC.FTS flag is 1 (frame transmission/wake-up transmission and reception started).

BER Flag (Bit Error Flag)

Only 0 can be written to this bit. When 1 is written to this bit, the value before the write is retained.
This bit becomes 1 when a bit error is detected. To set this bit to 0 before the next communication starts, write 0 to this bit in LIN operation mode.

PBER Flag (Physical Bus Error Flag)

Only 0 can be written to this bit. When 1 is written to this bit, the value before the write is retained.
This bit becomes 1 when a physical bus error is detected. To set this bit to 0 before the next communication starts, write 0 to this bit in LIN operation mode.

FTER Flag (Frame Timeout Error Flag)

Only 0 can be written to this bit. When 1 is written to this bit, the value before the write is retained.
This bit becomes 1 when a frame timeout error is detected. To set this bit to 0 before the next communication starts, write 0 to this bit in LIN operation mode.

FER Flag (Framing Error Flag)

Only 0 can be written to this bit. When 1 is written to this bit, the value before the write is retained.
This bit becomes 1 when a framing error is detected. To set this bit to 0 before the next communication starts, write 0 to this bit in LIN operation mode.

CSER Flag (Check Sum Error Flag)

Only 0 can be written to this bit. When 1 is written to this bit, the value before the write is retained.
This bit becomes 1 when a check sum error is detected. To set this bit to 0 before the next communication starts, write 0 to this bit in LIN operation mode.

27.2.16 Response Field Set Register (L0RFC)

Address: 0009 4014h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	FSM	CSM	RFT	RFDL[3:0]			
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b3 to b0	RFDL[3:0]	Response Field Data Length Setting	b3 b0 0 0 0 0 : 0 byte + check sum 0 0 0 1 : 1 byte + check sum 0 0 1 0 : 2 bytes + check sum : 0 1 1 1 : 7 bytes + check sum 1 0 0 0 : 8 bytes + check sum Settings other than above are prohibited.	R/W
b4	RFT	Response Field Transmit/Receive Direction Setting	0: Reception 1: Transmission	R/W
b5	CSM	Check Sum Select	0: Classic check sum 1: Enhanced check sum	R/W
b6	FSM	Frame Separate Mode Select	0: Non-frame separate mode 1: Frame separate mode	R/W
b7	—	Reserved	This bit is read as 0. The write value should be 0.	R/W

L0RFC register should be set when the L0TC.FTS bit is 0 (frame transmission/wake-up transmission and reception stopped).

RFDL[3:0] Bits (Response Field Data Length Setting)

These bits set the data length of the response field.
The data length can be set from 0 to 8 bytes, and the check sum size is not included in the data length.

RFT Bit (Response Field Transmit/Receive Direction Setting)

When this bit is set to 0, a response is received by the response field. In LIN wake-up mode, a wake-up is received (input signal Low time counting).
When this bit is set to 1, a response is transmitted by the response field. In LIN wake-up mode, a wake-up is transmitted.

CSM Bit (Check Sum Select)

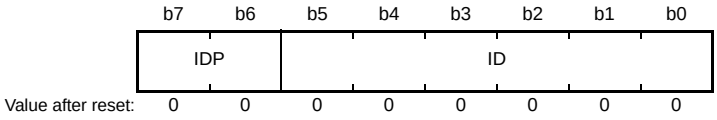
This bit sets the check sum mode.
When this bit is set to 0, classic check sum is selected.
When this bit is set to 1, enhanced check sum is selected.
If a frame timeout error is used (L0EDE.FTERE bit is 1), the frame timeout period differs according to the CSM bit setting. For details, refer to section 27.10, Error Status.

FSM Bit (Frame Separate Mode Select)

When this bit is set to 0, frame separate mode is not selected.
When this bit is set to 1, frame separate mode is selected.
In response reception (RFT bit is 0), the FSM bit setting has no effect on operation.
When making a transition to LIN self-test mode, set this bit to 0 before transition.
For details on frame separate mode, refer to section 27.7.1.1, Frame Separate Mode.

27.2.17 ID Buffer Register (L0IDB)

Address: 0009 4015



Bit	Symbol	Bit Name	Description	R/W
b5 to b0	ID	ID Setting	Set a 6-bit ID value to be transmitted by the ID field.	R/W
b7, b6	IDP	Parity Setting	Set the parity bits (P) to be transmitted by the ID field.	R/W

L0IDB register should be set when the L0TC.FTS bit is 0 (frame transmission/wake-up transmission and reception stopped).

In LIN self-test mode, the settings are as follows.

When the L0RFC.RFT bit = 1 (transmission)

The inverted value of the transmitted value can be read. The value to be transmitted can be written before communication.

When the L0RFC.RFT bit = 0 (reception)

The inverted value of the received value can be read. The value to be received can be written before communication.

ID Bit (ID Setting)

These bits set a 6-bit ID to be transmitted by the ID field in a LIN frame.

IDP Bit (Parity Setting)

These bits set the parity bits (P0 and P1) to be transmitted by the ID field in a LIN frame.

Since the parity is not automatically calculated, set the calculated value. Even if an erroneous calculation result is set, the set value will be transmitted.

27.2.18 Check Sum Buffer Register (L0CBR)

Address: 0009 4016h

	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Description	R/W
b7 to b0	Store the check sum data to be transmitted and received.	R/W

L0CBR register should be set when the L0TC.FTS bit is 0 (frame transmission/wake-up transmission and reception stopped).

In LIN operation mode, the settings are as follows.

- When the L0RFC.RFT bit = 1 (transmission)
  The transmitted value can be read. Writing is disabled.
- When the L0RFC.RFT bit = 0 (reception)
  The received value can be read. Writing is disabled.

In LIN self-test mode, the settings are as follows.

- When the L0RFC.RFT bit = 1 (transmission)
  The inverted value of the transmitted value can be read. Writing is disabled.
- When the L0RFC.RFT bit = 0 (reception)
  The inverted value of the received value can be read. The value to be received can be written before communication.

27.2.19 Data n Buffer Register (L0DBn) (n = 1 to 8)

Address: L0DB1 0009 4018h, L0DB2 0009 4019h, L0DB3 0009 401Ah, L0DB4 0009 401Bh, L0DB5 0009 401Ch, L0DB6 0009 401Dh, L0DB7 0009 401Eh, L0DB8 0009 401Fh

	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Description	Setting Range	R/W
b7 to b0	Set the data to be transmitted or read the received data.	00h to FFh	R/W

L0DBn register should be set in the following states.

In response transmission:

- L0RFC.RFT bit = 1 (transmission)
- L0RFC.FSM bit = 0 (non-frame separate mode)
- L0TC.FTS bit = 0 (frame transmission/wake-up transmission and reception stopped)

or

- L0RFC.RFT bit = 1 (transmission)
- L0RFC.FSM bit = 1 (frame separate mode)
- L0TC.RTS bit = 0 (response transmission stopped)

In response reception:
The received data is overwritten. When an error is detected, data up to the point where the reception was aborted is stored.

In LIN self-test mode, the settings are as follows.

- When the L0RFC.RFT bit = 1 (transmission)
  The inverted value of the transmitted value can be read. The value to be transmitted can be written before communication.
- When the L0RFC.RFT bit = 0 (reception)
  The inverted value of the received value can be read. The value to be received can be written before communication.

27.3 Operating Mode

The LIN module has the following four operating modes:

- LIN reset mode
- LIN operation mode
- LIN wake-up mode
- LIN self-test mode

In LIN reset mode, the power consumption can be reduced since the clock is not provided to the LIN module.
Figure 27.2 shows the transition processes between LIN operating modes, and Table 27.4 lists functions available in each operating mode.

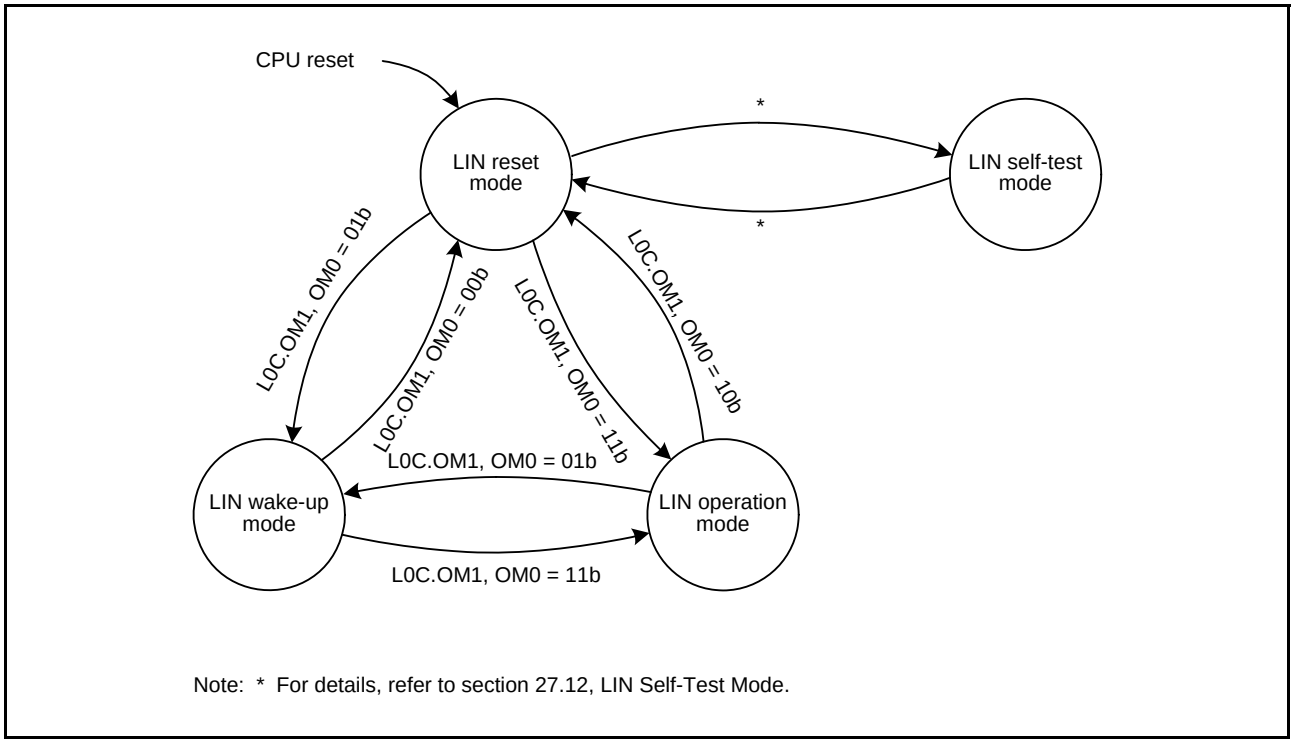


Figure 27.2 Operating Mode Transition

Table 27.4 Available Functions in Each Operating Mode

LIN Operation Mode	LIN Wake-up Mode	LIN Self-Test Mode
Header transmission Response transmission Response reception Error detection	Wake-up transmission Wake-up reception Error detection	Self-test

The transition to LIN reset mode, LIN operation mode, and LIN wake-up mode can be checked by reading the L0MST.OMM1, OMM0 bits.
For details on LIN self-test mode, refer to section 27.12, LIN Self-Test Mode.

27.3.1 LIN Reset Mode

LIN reset mode is activated by setting the L0C.OM1, OM0 bits to 00b or 10b (LIN reset mode), and the transition to LIN reset mode can be checked when the L0C.OM1, OM0 bits become 00b or 10b (LIN reset mode). In this mode, all LIN communication functions are stopped as well as fLIN.
The LIN module can enter LIN operation mode, LIN wake-up mode, or LIN self-test mode from LIN reset mode.

The following registers are initialized to their reset values after the LIN module enters LIN reset mode. The registers retain their initial values during LIN reset mode.

- L0TC
- L0ST
- L0EST

The following registers retain their previous values even after the LIN module enters LIN reset mode.

- LWBR
- LBRP0
- LBRP1
- LSTC (LSTC.LSTM bit only)
- L0MD
- L0BRK
- L0SPC
- L0WUP
- L0IE
- L0EDE
- L0RFC
- L0IDB
- L0DBn (n = 1 to 8)

27.3.2 LIN Operation Mode

LIN operation mode is activated by setting the L0C.OM1, OM0 bits to 11b, and the L0MST.OMM1, OMM0 bits become 11b.Set the transmit data after the L0MST bits have been set to 11b.

27.3.3 LIN Wake-up Mode

LIN wake-up mode is activated by setting the L0C.OM1, OM0 bits to 01b, and the L0MST.OMM1, OMM0 bits become 01b.

27.3.4 LIN Self-Test Mode

LIN self-test mode is activated by writing to the LSTC register, and the transition to LIN self-test mode can be checked when the LSTC.LSTM bit is set to 1.

27.4 Operational Overview

27.4.1 Header Transmission

Figure 27.3 shows the LIN module operation in header transmission, and Table 27.5 lists the processing in header transmission.

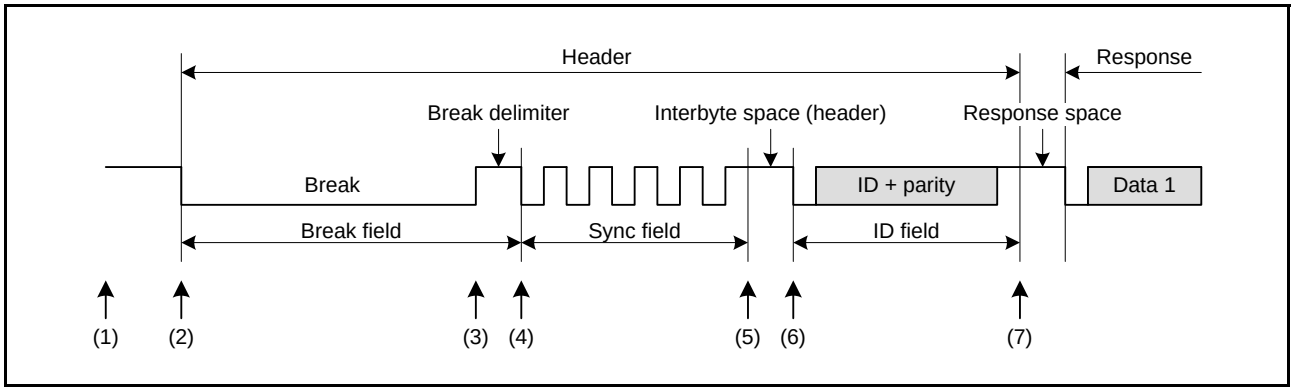


Figure 27.3 Operation in Header Transmission

Table 27.5 Processing in Header Transmission

	Software Processing	LIN Module Processing
(1)	Set the baud rate (see section 27.5, Baud Rate Generator). Set the L0IE.FTCIE bit to 1 (frame/wake-up transmit completion interrupt enabled), set the L0IE.FRCIE bit to 1 (frame/wake-up receive completion interrupt enabled), and set the L0IE.ERRIE bit to 1 (error detection interrupt enabled). Change the LIN module operating mode by the L0C.OM1, OM0 bits. Set the break width (13 to 28 Tbits) by the L0BRK.BLT[3:0] bits and set the break delimiter width (1 to 4 Tbits) by the L0BRK.BDT[1:0] bits. Set the interbyte space (header)/response space width (0 to 7 Tbits) by the L0SPC.IBSH[2:0] bits and set the interbyte space width (0 to 3 Tbits) by the L0SPC.IBS[1:0] bits. Set the ID value and parity value to L0IDB. Set the data length by the L0RFC.RFDL[3:0] bits, set the response transmit/receive direction by the L0RFC.RFT bit, and set the check sum mode by the L0RFC.CSM bit. Set the transmit data.	Wait for frame/wake-up transmission start by software (idle).
(2)	Set the L0TC.FTS bit to 1 (frame transmission/wake-up transmission and reception started).	Transmit the break Low.
(3)		Transmit the break delimiter.
(4)		Transmit the Sync field (55h).
(5)		Transmit the interbyte space (header).
(6)		Transmit the ID field.
(7)		Set the header transmit completion flag or error flag. Transmit the response space.

27.4.2 Response Transmission

Figure 27.4 shows the LIN module operation in response transmission, and Table 27.6 lists the processing in response transmission.

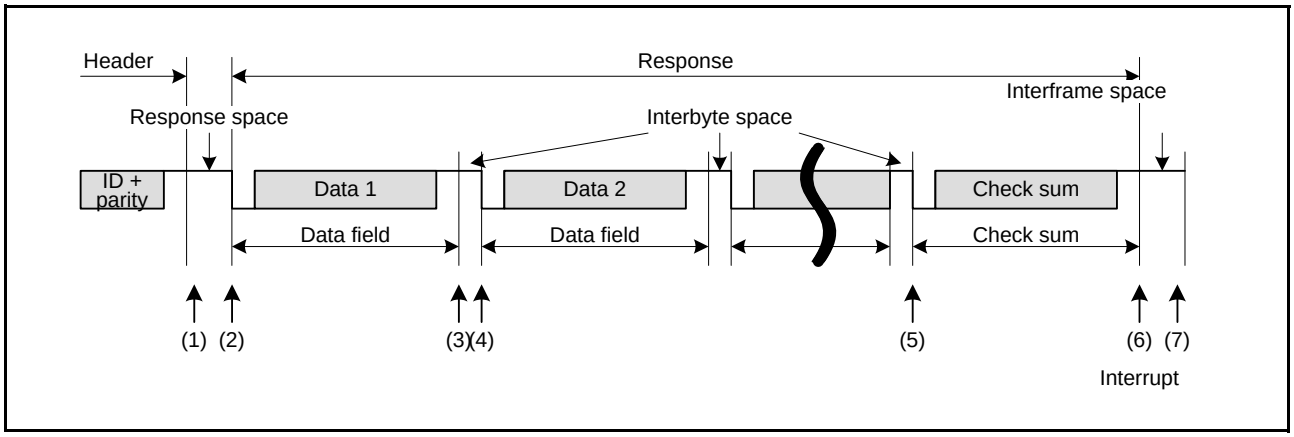


Figure 27.4 Operation in Response Transmission

Table 27.6 Processing in Response Transmission

	Software Processing	LIN Module Processing
(1)	(In frame separate mode) Set the L0TC.RTS bit to 1 (response transmission started). (In non-frame separate mode) Wait for generation of an interrupt request.	(In frame separate mode) Transmit the response space while waiting for response transmission to be started. (In non-frame separate mode) Go to (2) if the response space transmission has been completed.
(2)	Wait for generation of an interrupt request.	Transmit Data 1.
(3)		Transmit the interbyte space.
(4)		Transmit Data 2. Transmit the interbyte space. Transmit Data 3. Transmit the interbyte space. (Repeat this processing for the data length specified by the L0RFC.RFDL[3:0] bits. Abort it when the L0EST.BER flag becomes 1 (bit error detected). If an error occurs, check sum transmission in (5) is not executed.) : :
(5)		Transmit the check sum.
(6)		Set the frame/wake-up transmit completion flag or error flag. Set the L0TC.FTS bit to 0 (frame transmission/wake-up transmission and reception stopped) and set the L0TC.RTS bit to 0 (response transmission stopped).
(7)	Processing after communication: Check the L0ST register and clear flags to 0.	Idle

27.4.3 Response Reception

Figure 27.5 shows the LIN module operation in response reception, and Table 27.7 lists the processing in response reception.

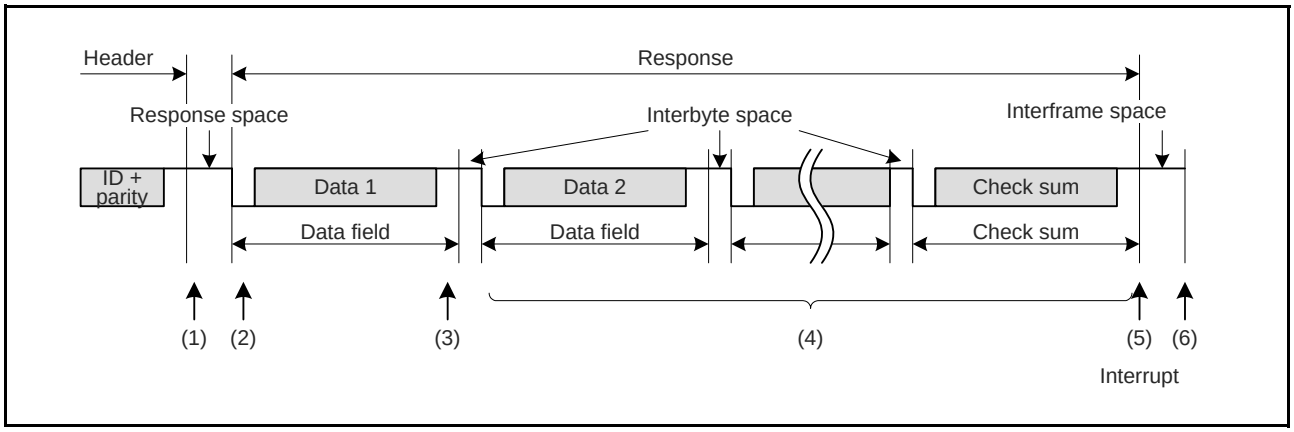


Figure 27.5 Operation in Response Reception

Table 27.7 Processing in Response Reception

	Software Processing	LIN Module Processing
(1)	Wait for generation of an interrupt request (without processing).	Wait for detection of a start bit.
(2)	Wait for generation of an interrupt request.	Receive Data 1 due to a start bit detected.
(3)		Set the Data 1 receive completion flag.
(4)		Receive Data 2 due to a start bit detected. Receive Data 3 due to a start bit detected. (Repeat this processing for the data length specified by the L0RFC.RFDL[3:0] bits. Abort it when any bit in the L0EST register becomes 1 (error is detected). If an error occurs, check sum judgement in (5) is not executed.) : : Receive check sum due to a start bit detected.
(5)		·Judge the check sum. ·Set the frame/wake-up receive completion flag or error flag. ·Set the L0TC.FTS bit to 0 (frame transmission/wake-up transmission and reception stopped).
(6)	Processing after communication: Read the received data. Check the L0ST register and clear flags to 0.	Idle

27.5 Baud Rate Generator

The LIN system clock (fLIN) is generated by the LIN communication clock source divided by the baud rate generator. This fLIN, divided by 16, is used as the bit rate. The reciprocal of the bit rate is called bit time, expressed as "Tbit". The LBRP0 register should be set so that fa is 307200 Hz (19200 × 16). Therefore, fa = 19200 × 16, fb = 9600 × 16, and fc = 2400 × 16. Then they are divided by 16 in the bit timing generator, which results in 19200 bps, 9600 bps, and 2400 bps, respectively. The baud rate of 10417 bps is generated by the LBRP1 setting.

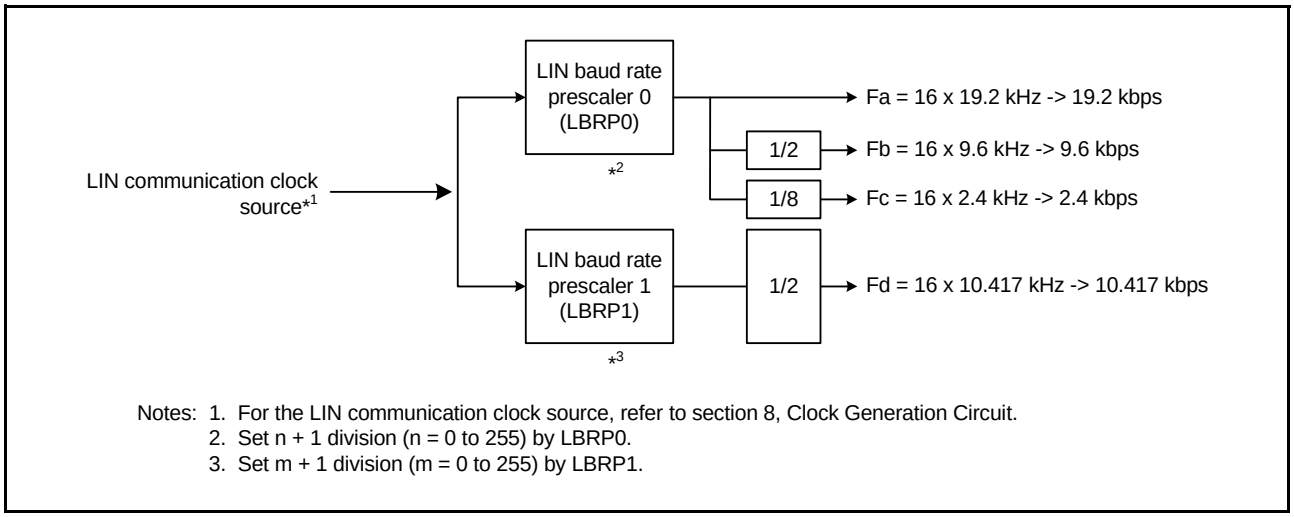


Figure 27.6 Block Diagram of Baud Rate Generation

Table 27.8 and Table 27.9 list the baud rates (19200, 9600, 2400, and 10417 bps) for each peripheral clock frequency, and their error.

Table 27.8 Baud Rate Generation Examples (19200 bps, 9600 bps, and 2400 bps)

LIN Communication Clock Source	Baud Rate Generator 0 (Divided by N + 1)	Baud Rate to be Generated						Error
		fa Selection		fb Selection		fc Selection		
50 MHz	162	19290.12	(19200 bps)	9645.06	(9600 bps)	2411.27	(2400 bps)	+0.47%
40 MHz	130	19230.77	(19200 bps)	9615.38	(9600 bps)	2403.85	(2400 bps)	+0.16%
25 MHz	81	19290.12	(19200 bps)	9645.06	(9600 bps)	2411.27	(2400 bps)	+0.47%
24 MHz	78	19230.77	(19200 bps)	9615.38	(9600 bps)	2403.85	(2400 bps)	+0.16%
20 MHz	65	19230.77	(19200 bps)	9615.38	(9600 bps)	2403.85	(2400 bps)	+0.16%
16 MHz	52	19230.77	(19200 bps)	9615.38	(9600 bps)	2403.85	(2400 bps)	+0.16%
12 MHz	39	19230.77	(19200 bps)	9615.38	(9600 bps)	2403.85	(2400 bps)	+0.16%
10 MHz	65	9615.38	(9600 bps)	—	—	—	—	+0.16%
8 MHz	26	19230.77	(19200 bps)	9615.38	(9600 bps)	2403.85	(2400 bps)	+0.16%
6 MHz	39	9615.38	(9600 bps)	—	—	—	—	+0.16%
	156	2403.85	(2400 bps)					+0.16%
5 MHz	130	2403.85	(2400 bps)	—	—	—	—	+0.16%
4 MHz	13	19230.77	(19200 bps)	9615.38	(9600 bps)	2403.85	(2400 bps)	+0.16%
2 MHz	13	9615.38	(9600 bps)	—	—	—	—	+0.16%
	52	2403.85	(2400 bps)					+0.16%

—: Corresponding baud rate cannot be generated

Table 27.9 Baud Rate Generation Examples (10417 bps)

LIN Communication Clock Block	Baud Rate Generator 1 (Divided by M + 1)	Baud Rate to be Generated fd Selection	Error
40 MHz	120	10416.67	–0.003%
25 MHz	75	10416.67	–0.003%
24 MHz	72	10416.67	–0.003%
20 MHz	60	10416.67	–0.003%
16 MHz	48	10416.67	–0.003%
12 MHz	36	10416.67	–0.003%
10 MHz	30	10416.67	–0.003%
8 MHz	24	10416.67	–0.003%
6 MHz	18	10416.67	–0.003%
5 MHz	15	10416.67	–0.003%
4 MHz	12	10416.67	–0.003%
2 MHz	6	10416.67	–0.003%

27.6 Data Transmission and Reception

27.6.1 Data Transmission

The LIN module transmits one bit data per Tbit.
The transmitted data returns to the input pin for data reception via the LIN transceiver. Then the received data is compared to the transmitted data and the result is stored in the L0EST.BER flag (see section 27.10, Error Status). The timing to sample the received data is at the 13th clock (position of 81.25%) when 1 Tbit is generated by 16 fLIN.
Figure 27.7 shows the data transmission timing.

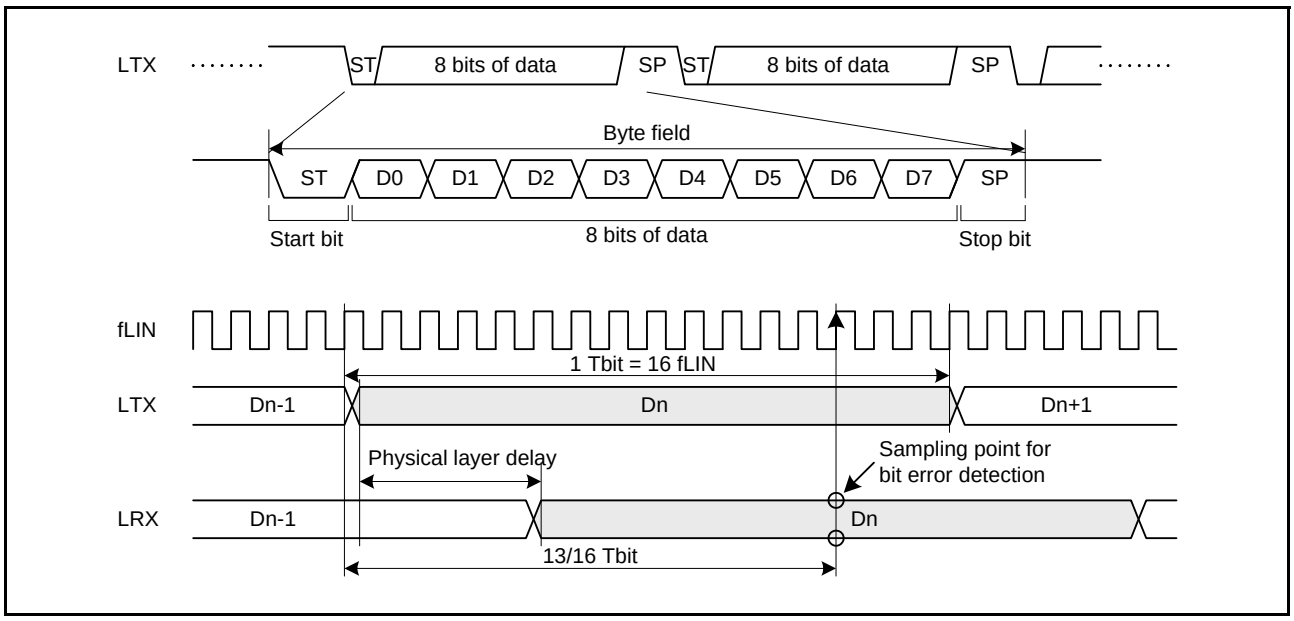


Figure 27.7 Data Transmission Timing

27.6.2 Data Reception

The LIN module receives data using a synchronized LRX signal (internal signal) generated by synchronizing the input signal from the LRX pin with fLIN.

The byte field of this synchronized LRX signal is synchronized with fLIN at the falling edge of the start bit. The start bit is recognized if the synchronized LRX signal still remains low when being re-sampled 0.5 Tbits after the falling edge was detected. If the LRX signal remains low after exiting reset mode or if it is held high on re-sampling, no start bit is found.

Once the start bit is detected, data bits are sampled every 1 Tbit.

Figure 27.8 shows the data reception timing.

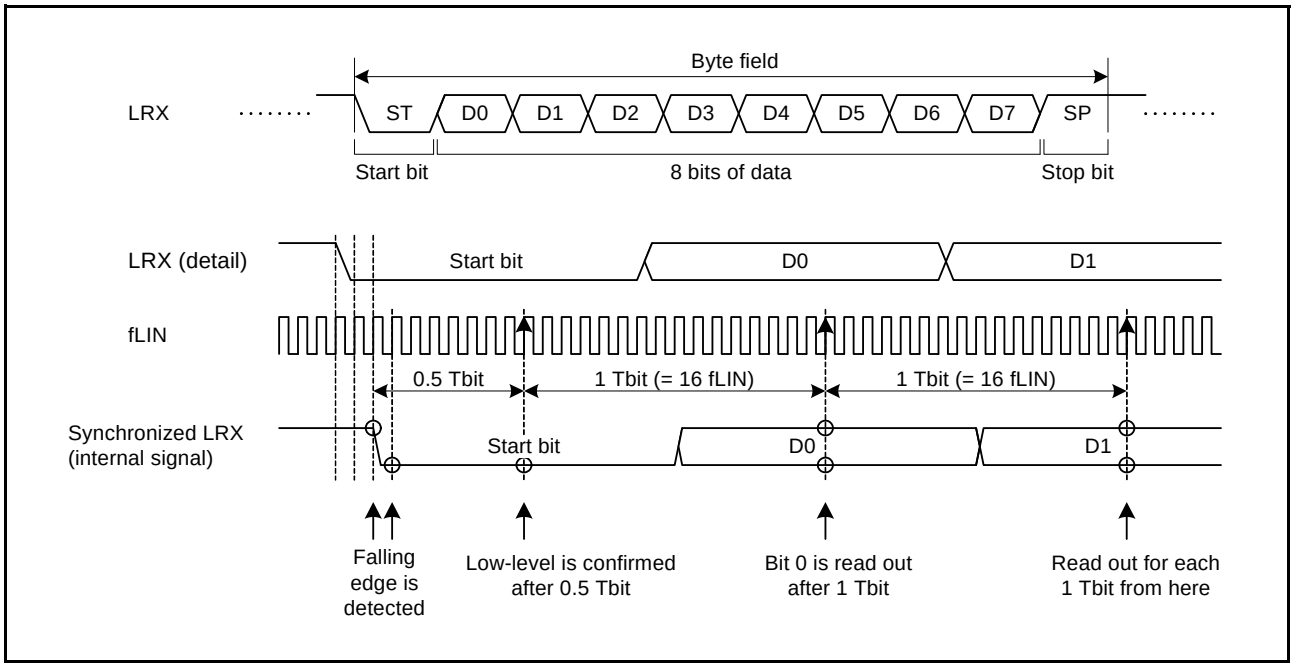


Figure 27.8 Data Reception Timing

27.7 Buffer Processing of Data to be Transmitted and Received Data

The buffer processing in consecutive data transmission and reception by the LIN module is described below.

27.7.1 Transmission of LIN Frame

In 8-byte transmission, the contents stored in registers L0DB1 to L0DB8 are transmitted to Data 1 to Data 8 areas of the LIN frame in order. In 4-byte transmission, the contents stored in registers L0DB1 to L0DB4 are transmitted to Data 1 to Data 4 areas of the LIN frame, and the contents stored in registers L0DB5 to L0DB8 are not transmitted. The transmitted check sum data is stored in the L0CBR register.
Figure 27.8 shows LIN transmission processing and buffers.

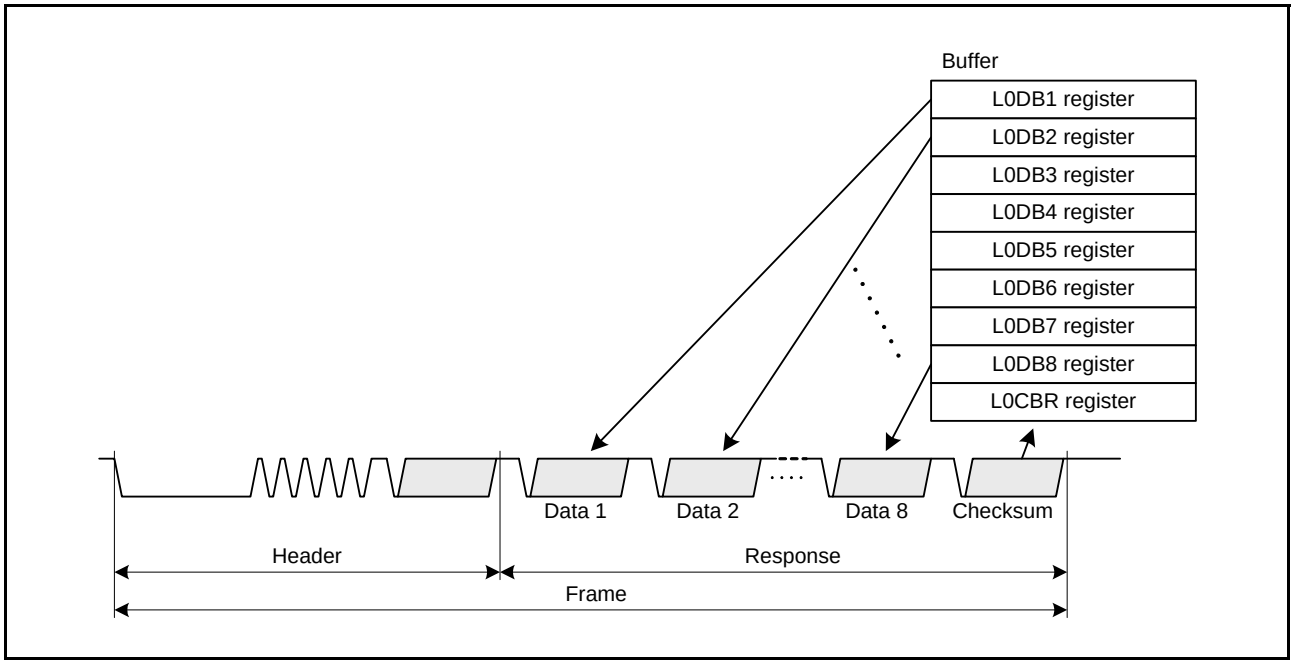


Figure 27.9 LIN Transmission Processing and Buffers

27.7.1.1 Frame Separate Mode

Frame separate mode is selected by setting the L0RFC.FSM bit to 1.
In frame separate mode, a header and response can be transmitted according to separate transmit start requests.
When the header transmission has been completed, the L0ST.HTRC flag becomes 1 (header transmission completed).

27.7.2 Reception of LIN Frame

In 8-byte reception, the contents of Data 1 to Data 8 areas of the LIN frame are stored in registers L0DB1 to L0DB8 in order upon every completion of stop bit reception. In 4-byte reception, the contents of Data 1 to Data 4 areas of the LIN frame are stored in registers L0DB1 to L0DB4, and no data is stored in registers L0DB5 to L0DB8. The received check sum data is stored in the L0CBR register.

Figure 27.9 shows LIN reception processing and buffers.

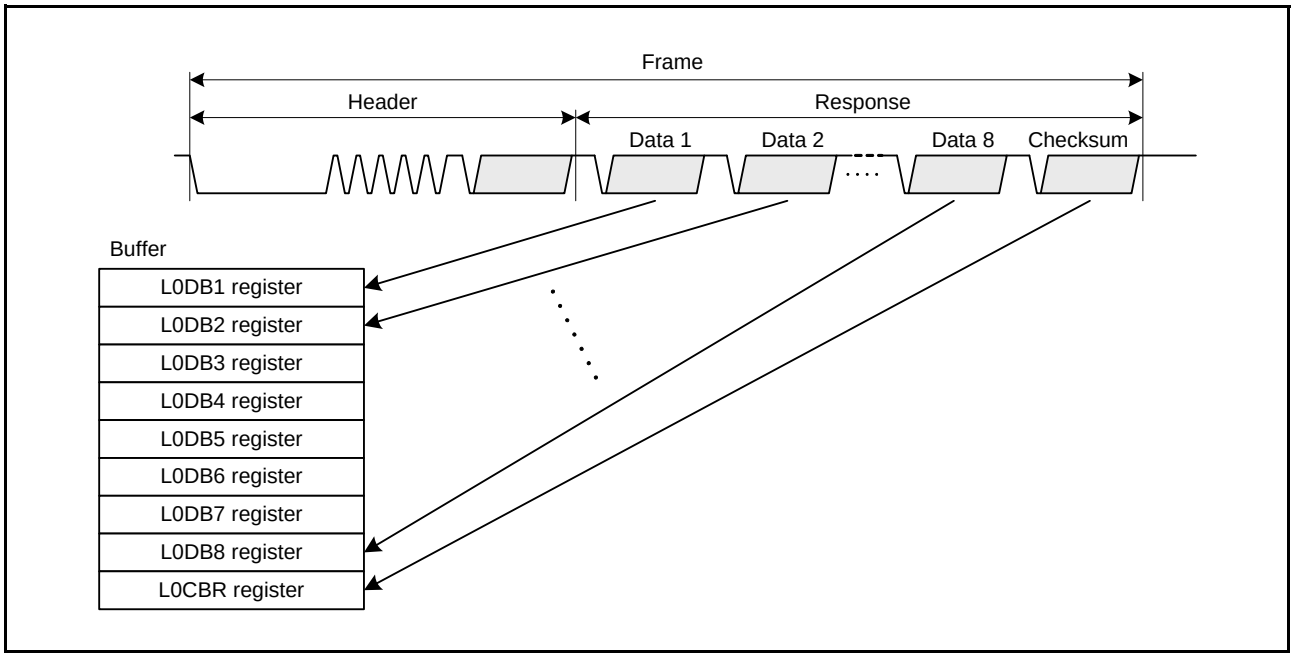


Figure 27.10 LIN Reception Processing and Buffers

27.7.2.1 Data 1 Reception

When the first byte of data reception is completed, the L0ST.D1RC flag becomes 1 (data 1 reception completed).

27.8 Wake-up Transmission and Reception

Wake-up transmission and reception are available in LIN wake-up mode.

27.8.1 Operation in Wake-up Transmission

In LIN wake-up mode, if the L0RFC.RFT bit is set to 1 (transmission) and the L0TC.FTS bit is set to 1 (frame transmission/wake-up transmission and reception started), the wake-up signal is output at the output pin. Low time of the wake-up signal is set by the L0WUP.WUTL[3:0] bits.
When Low of wake-up is output without any bit error detected, the L0ST.FTC flag becomes 1 (frame or wake-up transmission completed). If the L0IE.FTCIE bit is set to 1 (frame/wake-up transmit completion interrupt enabled) at this time, an interrupt request is generated.
When a bit error is detected, the wake-up transmission is aborted and the L0EST.BER flag becomes 1 (bit error detected).
Figure 27.11 shows the wake-up transmission timing.

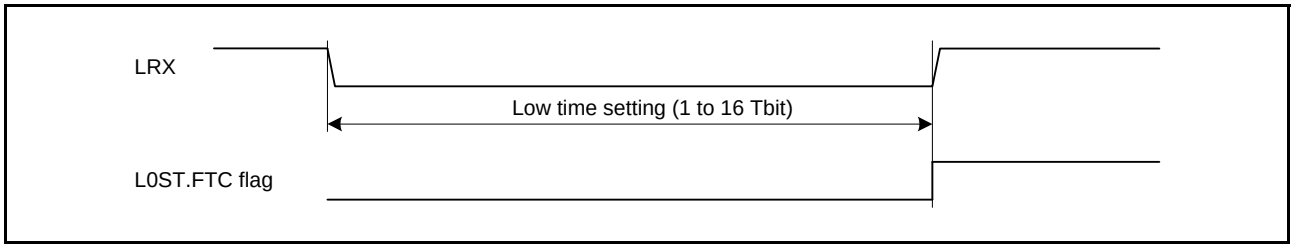


Figure 27.11 Wake-up Transmission Timing

27.8.2 Operation in Wake-up Reception

The LIN module uses the input signal Low time counting function for detecting a wake-up.
The input signal Low time counting function is used to measure the Low time of the input signal at the LRX pin by counting at the same sampling timing as that of data reception. The Low time to be measured varies depending on the setting of the LWBR.LWBR0 bit. When LIN Specification Package Revision 1.3 is used, set the LWBR.LWBR0 bit to 0. This allows the input signal Low time to be measured for 2.5 or more Tbits of fLIN. When LIN Specification Package Revisions 2.0 and 2.1 are used, set the LWBR.LWBR0 bit to 1. This allows the input signal Low time to be measured for 130 µs or more.
To use this function, set the L0RFC.RFT bit to 0 (reception) and the L0TC.FTS bit to 1 (frame transmission/wake-up transmission and reception started) in LIN wake-up mode.
When the Low time to be measured is reached, the L0ST.FRC flag becomes 1 (frame or wake-up reception completed). If the L0IE.FRCIE bit is set to 1 (frame/wake-up receive completion interrupt enabled) at this time, an interrupt request is generated.

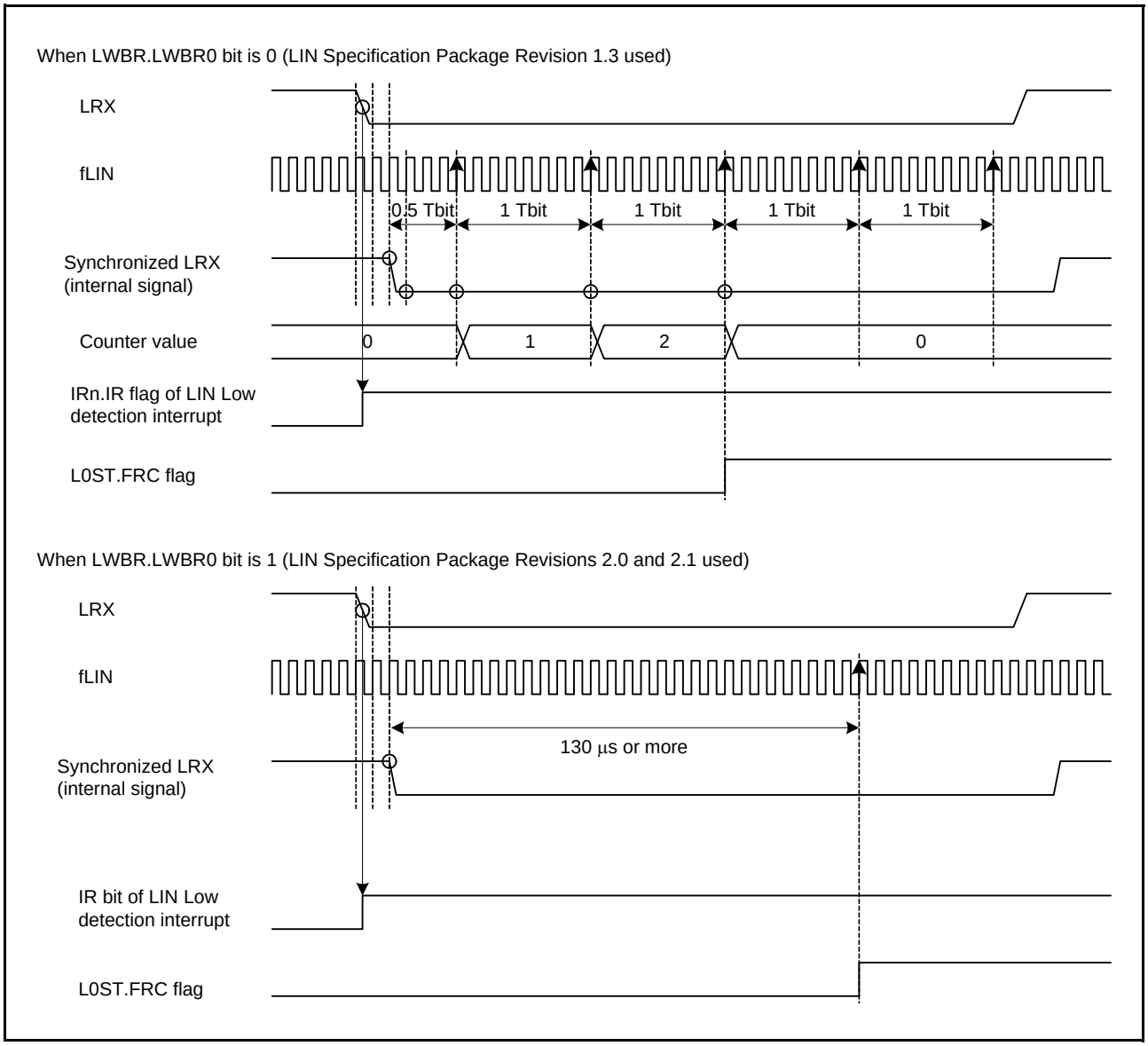


Figure 27.12 Input Signal Low Time Counting Function

During wake-up transmission, the input signal Low time counting function is not workable.

27.8.3 Wake-up Collision

When the master and slave transmit wake-up signals simultaneously, a signal collision occurs on the LIN bus. However, no collision of wake-up signals is detected in the LIN module.

27.9 Operating Status

The LIN module detects seven types of operating status.
The three states that can generate an interrupt request are: frame/wake-up transmit completion, frame/wake-up receive completion, and error detection.
Table 27.10 lists the operating status types.

Table 27.10 Operating Status Types

Operating Status	Status Setting Condition	Status Clearing Conditions	Status Detectable Operating Modes	Corresponding Bit
LIN mode	When the LIN module has actually entered LIN operation mode after the L0C.OM1 bit was set to select LIN operation mode	When the LIN module has actually entered LIN wake-up mode after the L0C.OM1 bit was set to select LIN wake-up mode	LIN operation mode LIN wake-up mode	L0MST.OMM1 bit
Reset	When the LIN module has actually exited LIN reset mode after the L0C.OM0 bit was set to select non-LIN reset mode	When the LIN module has actually entered LIN reset mode after the L0C.OM1 bit was set to select LIN reset mode	All modes	L0MST.OMM0 bit
Frame/ wake-up transmit completion	When a response field or wake-up signal transmission has been successfully completed	When the next communication starts Clearing by software On transition to LIN reset mode	LIN operation mode LIN wake-up mode	L0ST.FTC flag
Frame/ wake-up receive completion	When a response field or wake-up signal reception has been successfully completed	When the next communication starts Clearing by software On transition to LIN reset mode	LIN operation mode LIN wake-up mode	L0ST.FRC flag
Error detection	When any of flags L0EST.CSER, FER, FTER, PBER, and BER becomes 1 (error detected)	When the next communication starts Clearing by software*1 On transition to LIN reset mode	LIN operation mode LIN wake-up mode	L0ST.ERR flag
Data 1 receive completion	When the reception of the first one byte of a response frame has been completed with the L0RFC.RFT bit set to 0 (reception)*2	When the next communication starts Clearing by software On transition to LIN reset mode	LIN operation mode	L0ST.D1RC flag
Header transmit completion	When a header field transmission has been successfully completed	When the next communication starts Clearing by software On transition to LIN reset mode	LIN operation mode	L0ST.HTRC flag

Note 1. By writing 0 to flags L0EST.CSER, FER, FTER, PBER, and BER in LIN operation mode, the L0ST.ERR flag becomes 0.
Note 2. This status is not detected when the L0RFC.RFDL[3:0] bits are set to 0000b (0 byte + check sum).

27.10 Error Status

27.10.1 Error Status Types

The LIN module detects five types of error status. These error states can be checked by the bits in the LEST register. Table 27.11 lists the error status types.

Table 27.11 Error Status Types

Error Status	Error Detecting Condition (Clearing to 0 by Software)	Error Detectable Operating Modes	Communication Processing	Detection Enabled/ Disabled	Corresponding Bit
Bit error	When the transmitted data does not match with that on the LIN bus monitored by the pin for reception*1	LIN operation mode LIN wake-up mode	Abort	Selectable	L0EST.BER flag
Physical bus error	If the LIN bus detects high when the break field is transmitted If the LIN bus detects low when the break delimiter is transmitted If the LIN bus detects high when the wake-up is transmitted	LIN operation mode LIN wake-up mode	Abort	Selectable	L0EST.PBER flag
Frame timeout error	When frame transmission/reception is not completed within a specified period of time*2	LIN operation mode	Abort	Selectable	L0EST.FTER flag
Framing error	When the stop bit of each data byte is Low in response frame reception processing	LIN operation mode	Abort	Selectable	L0EST.FER flag
Check sum error	When the check sum judgement of response frame reception processing results in an error	LIN operation mode	—	Non-selectable	L0EST.CSER flag

Note 1. When a bit error is detected, the processing is aborted after the stop bit is transmitted. If it is detected in a non-data space, such as an interbyte space, the transmission processing is aborted after a check in that space is completed. If a bit error is detected during wake-up transmission, the wake-up transmission is aborted immediately after the error bit is transmitted.

Note 2. The timeout period depends on the response field data length (L0RFC.RFDL[3:0] bits) and the selected check sum (L0RFC.CSM bit), and can be calculated as follows:
When classic check sum is selected (L0RFC.CSM bit = 0)
Timeout period = 49 + (data bytes + 1) × 14 [Tbit]
When enhanced check sum is selected (L0RFC.CSM bit = 1)
Timeout period = 48 + (data bytes + 1) × 14 [Tbit]
The above timeout period will exceed the value of TFRAME_MAX shown in LIN Specification Package Revision 1.3 when classic check sum is selected, and the value of TFRAME_MAX shown in LIN Specification Package Revisions 2.0 and 2.1 when enhanced check sum is selected.

27.10.2 Target Areas for LIN Error Detection

Figure 27.13 shows the areas which the LIN module monitors for error detection.

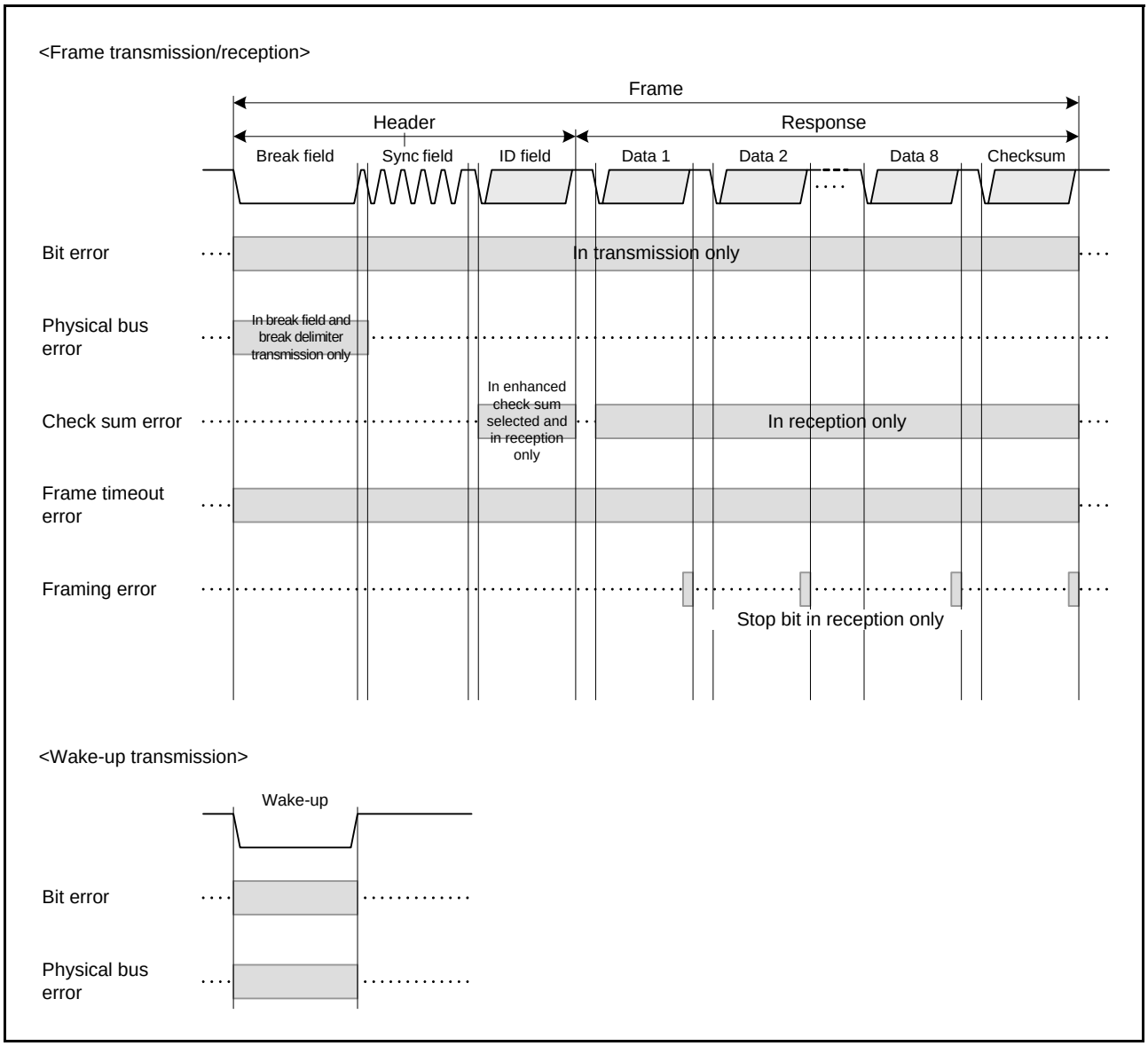


Figure 27.13 LIN Error Detection Target Areas

27.11 Interrupts

The interrupt request generated by the LIN module is the LIN interrupt.
There are three interrupt sources: frame/wake-up transmit completion, frame/wake-up receive completion, and error detection.
Interrupt requests by the three interrupt sources of frame/wake-up transmit completion, frame/wake-up receive completion, and error detection are aggregated by logical OR as a single interrupt request "LIN interrupt".
The respective interrupt request is output when the corresponding flag in the L0ST register becomes 1 while the corresponding bit in the L0IE register is set to 1 (interrupt enabled). However, while the corresponding bit in the LOST register is 1, the interrupt request is ignored. Therefore, set the corresponding flag to 0 to enable the interrupt.
Figure 27.14 shows a block diagram of the LIN interrupt.

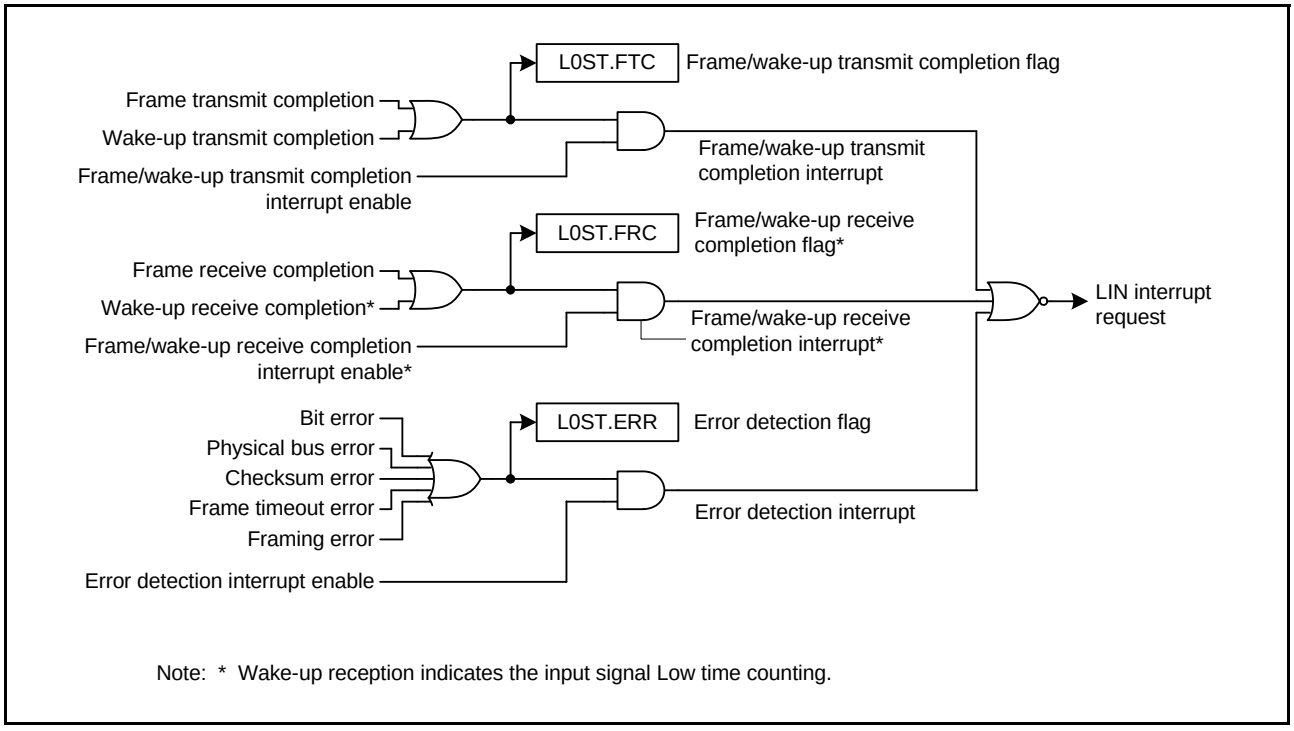


Figure 27.14 Block Diagram of LIN Interrupt

27.12 LIN Self-Test Mode

The LIN module has LIN self-test mode. Once the LIN module enters LIN self-test mode, it is disconnected from the LIN bus, and the internal LTX is looped back to the internal LRX (loop back).
LIN self-test mode operates in the following states.

- In LIN self-test mode
- Wake-up is not supported
- Frame separate mode is not supported
- The baud rate generator is set to the fastest settings (LBRP0 = 00h, LBRP1 = 00h, and L0MD.LCKS[1:0]bits = 00b)

Do not enter LIN wake-up mode.
Before entering LIN self-test mode, set the L0RFC.FSM bit to 0 (non-frame separate mode).
The baud rate setting is automatic in LIN self-test mode. When entering LIN reset mode from LIN self-test mode, the automatic setting is set back to the setting prior to LIN self-test mode.
Other settings are retained and remain valid when entering LIN self-test mode, and when entering LIN reset mode from LIN self-test mode.
Registers L0ST and L0EST remain functional, but the L0EST.FER, PBER, and BER flags cannot detect any errors at the loop back, and do not become 1.

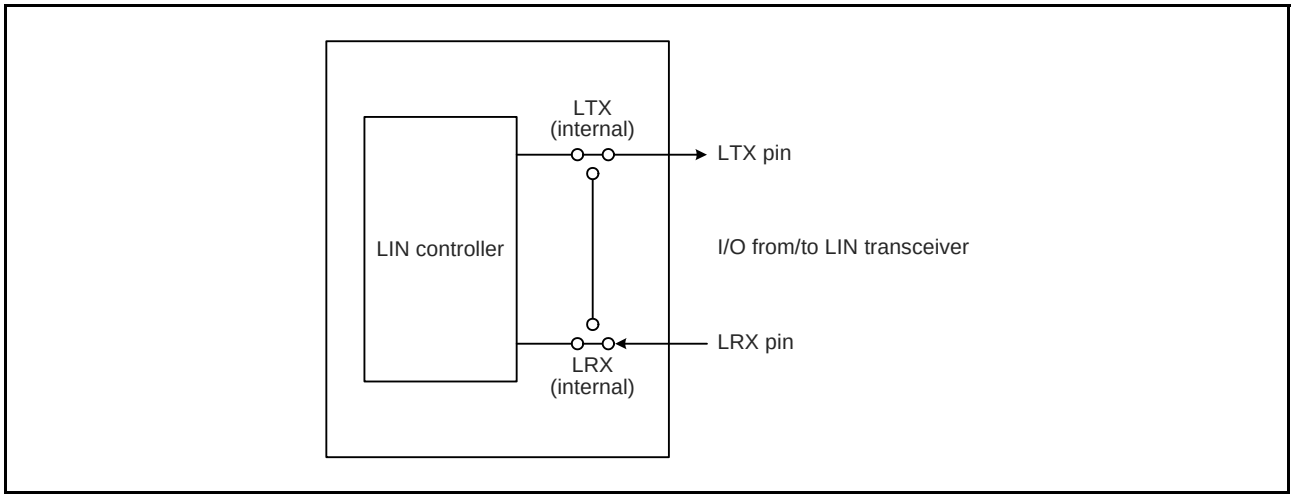


Figure 27.15 LIN Operation Mode Connection

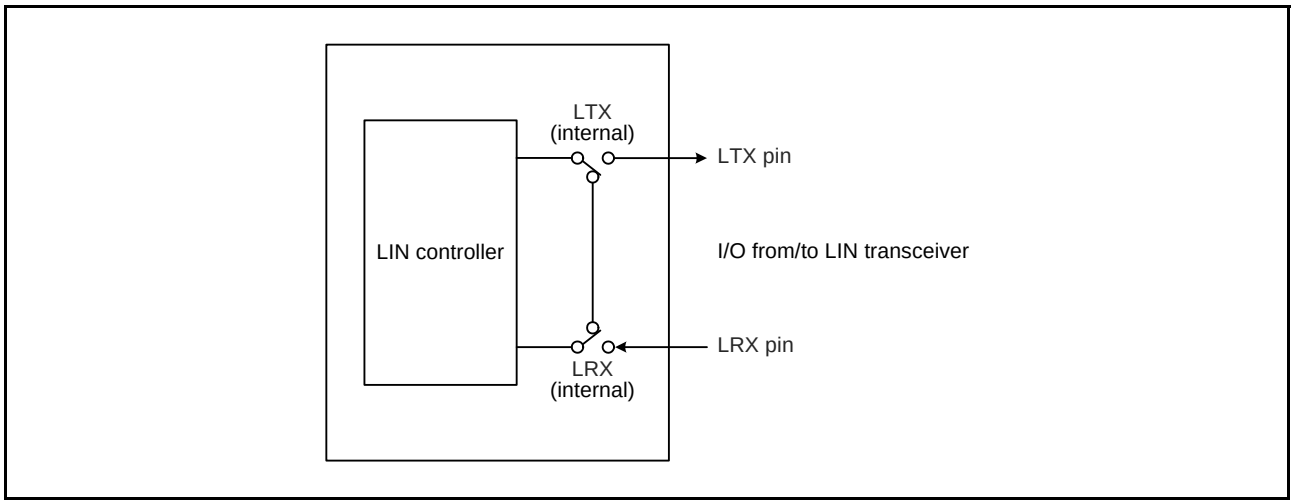


Figure 27.16 LIN Self-Test Mode Connection

27.12.1 Entry into LIN Self-Test Mode

To enter LIN self-test mode, a particular key sequence must be used. In this key sequence, the user has to do three consecutive writes to the LIN self-test control register as follows.

- Enter LIN reset mode.
- First write: LSTC register = 1010 0111 (A7h)
- Second write: LSTC register = 0101 1000 (58h)
- Third write: LSTC register = 0000 0001 (01h)

If the first key is written twice, then the sequence is broken and must be restarted.
If this sequence is broken by a write access to any other LIN register, then it must be restarted.

LIN self-test mode does not support frame separate mode. Two tests can be carried out.

- LIN self-test mode (transmission): Header transmission and response transmission
- LIN self-test mode (reception): Header transmission and response reception

27.12.2 Transmission in LIN Self-Test Mode

The following steps are to be performed to execute the LIN self-test.

- Write 11b to the L0C.OM1, OM0 bits, and then confirm the L0MST.OMM1, OMM0 bits are set to 11b.
- Set the L0RFC.RFT bit to 1 (transmission).
- Set the frame configuration to be transmitted.
- Set the L0TC.FTS bit to 1 (frame transmission/wake-up transmission and reception started).
- LIN self-test mode (transmission) is executed. Interrupt generation and update of status and error status are appropriately executed. Check sum is automatically calculated by the LIN module.
- If transmission is completed, the inverted value of the frame data after looped back is stored in registers L0IDB, L0CBR, and L0DBn (stored as an inverted value to compare the transmitted value and looped back value) (n = 1 to 8).
- If transmission is not completed due to an error, the corresponding error flag is set.

27.12.3 Reception in LIN Self-Test Mode

The following steps are to be performed to execute the LIN self-test.

- Enter LIN self-test mode.
- Set the L0RFC.RFT bit to 0 (reception).
- Set the frame configuration to be received. Since check sum is not automatically calculated, store the calculated value. A check sum error can be tested by setting an erroneous calculation result in the check sum.
- Set the L0TC.FTS bit to 1 (frame transmission/wake-up transmission and reception started).
- LIN self-test mode (reception) is executed. Interrupt generation and update of status and error status are appropriately executed.
- If reception is completed, the inverted value of the frame data after looped back is stored in registers L0IDB, L0CBR, and L0DBn (stored as an inverted value to compare the set value and received value after looped back).(n = 1 to 8)
- If reception is not completed due to an error, the corresponding error flag is set.

27.12.4 Exit from LIN Self-Test Mode

To exit LIN self-test mode, perform the following step.

- Enter LIN reset mode.
- (When the L0MST.OMM1, OMM0 bits are not 11b, write 11b to the L0C.OM1, OM0 bits, and then confirm the L0MST.OMM1, OMM0 bits are set to 11b before entering LIN reset mode.)

28. 12-Bit A/D Converter (S12ADA)

28.1 Overview

The RX62T Group has two units of 12-bit successive approximation A/D converter. Up to 4-channel analog inputs can be selected in each unit.

The A/D converter has two types of operating mode: single mode in which analog input of one channel is converted only once and scan mode in which analog inputs of up to four channels are sequentially converted.

Table 28.1 lists the specifications of the A/D converter and Table 28.2 shows the functions of the A/D converter. Figure 28.1 shows a block diagram of the A/D converter.

Table 28.1 Specifications of A/D Converter

Item	Specifications
Number of units	Two units (S12AD0 and S12AD1)
Input channels	Eight channels (four channels x two units)
A/D conversion method	Successive approximation method
Resolution	12 bits
Conversion time	1.0 μs per 1 channel (when operating with A/D conversion clock ADCLK = 50 MHz and AVCC = 4.0 to 5.5V) 2.0 μs per 1 channel (when operating with A/D conversion clock ADCLK = 25 MHz and AVCC = 3.0 to 3.6V)
A/D conversion clock	Four types: PCLK, PCLK/2, PCLK/4, PCLK/8
Data registers	Ten data registers The A/D conversion result is held in a 12-bit A/D data register. For AN000 and AN100 inputs, two A/D data registers are provided, which are switched according to the trigger type.
Operating modes	Single mode: Analog inputs of one channel are converted only once. Scan mode Single-cycle scan mode: Analog inputs of up to four channels are converted only once. Continuous scan mode: Analog inputs of up to four channels are converted repeatedly. 2-channel scan mode:Channels in each unit are divided into two groups and the conversion startup source can be separately selected for each group.
Conditions of A/D conversion start	Software trigger Conversion start trigger by the multifunction timer pulse unit 3 (MTU3) or general PWM timer (GPT). External trigger A/D conversion can be externally triggered from the ADTRG0# pin in S12AD0 and from the ADTRG1# pin in S12AD1.
Function	Sample-and-hold function (three channels per unit) A dedicated sample-and-hold circuit is provided for each of channels 0 to 2 (AN000 to AN002) of S12AD0 and channels 0 to 2 (AN100 to AN102) of S12AD1, which enables simultaneous sampling in multiple channels (up to three channels) in each unit. Self-diagnostic functions for A/D converter Input signal amplification function provided through programmable gain amplifier (three channels per unit) Window comparator function (three channels per unit)
Interrupt source	Interrupt request (S12ADI) can be generated on completion of A/D conversion in each unit. A S12ADI interrupt can activate the data transfer controller (DTC). Interrupt request (CMPI) can be generated when a specified comparison condition is detected (can also be used for a POE source).
Power-down function	Module stop state can be specified in each unit.

Table 28.2 Functions of A/D Converter

Item			Unit 0 (S12AD0)	Unit 1 (S12AD1)
Analog input channel			AN000 to AN003	AN100 to AN103
A/D conversion start conditions	Software	Software trigger	Enabled	Enabled
	External trigger	Trigger pin	ADTRG0#	ADTRG1#
	Trigger from MTU3	Compare match/input capture in MTU0.TGRA	TRGA0N	TRGA0N
		Compare match/input capture in MTU1.TGRA	TRGA1N	TRGA1N
		Compare match/input capture in MTU2.TGRA	TRGA2N	TRGA2N
		Compare match/input capture in MTU3.TGRA	TRGA3N	TRGA3N
		Compare match/input capture in MTU4.TGRA, or MTU4.TCNT underflow (trough) in complementary PWM mode	TRGA4N	TRGA4N
		Compare match/input capture in MTU6.TGRA	TRGA6N	TRGA6N
		Compare match/input capture in MTU7.TGRA, or MTU7.TCNT underflow (trough) in complementary PWM mode	TRGA7N	TRGA7N
		Compare match in MTU0.TGRE	TRG0N	TRG0N
		Compare match between MTU4.TADCORA and MTU4.TCNT	TRG4AN	TRG4AN
		Compare match between MTU4.TADCORB and MTU4.TCNT	TRG4BN	TRG4BN
		Compare match between MTU4.TADCORA and MTU4.TCNT, or compare match between MTU4.TADCORB and MTU4.TCNT	TRG4AN or TRG4BN	TRG4AN or TRG4BN
		Compare match between MTU4.TADCORA and MTU4.TCNT and compare match between MTU4.TADCORB and MTU4.TCNT (when interrupt skipping function 2 is used)	TRG4ABN	TRG4ABN
		Compare match between MTU7.TADCORA and MTU7.TCNT	TRG7AN	TRG7AN
		Compare match between MTU7.TADCORB and MTU7.TCNT	TRG7BN	TRG7BN
		Compare match between MTU7.TADCORA and MTU7.TCNT, or compare match between MTU7.TADCORB and MTU7.TCNT	TRG7AN or TRG7BN	TRG7AN or TRG7BN
		Compare match between MTU7.TADCORA and MTU7.TCNT and compare match between MTU7.TADCORB and MTU7.TCNT (when interrupt skipping function 2 is used)	TRG7ABN	TRG7ABN

Table 28.2 Functions of A/D Converter

Item			Unit 0 (S12AD0)	Unit 1 (S12AD1)
A/D conversion start conditions	Trigger from GPT	Compare match in GPT0.GTADTRA	GTADTRA0N	GTADTRA0N
		Compare match in GPT0.GTADTRB	GTADTRB0N	GTADTRB0N
		Compare match in GPT1.GTADTRA	GTADTRA1N	GTADTRA1N
		Compare match in GPT1.GTADTRB	GTADTRB1N	GTADTRB1N
		Compare match in GPT2.GTADTRA	GTADTRA2N	GTADTRA2N
		Compare match in GPT2.GTADTRB	GTADTRB2N	GTADTRB2N
		Compare match in GPT3.GTADTRA	GTADTRA3N	GTADTRA3N
		Compare match in GPT3.GTADTRB	GTADTRB3N	GTADTRB3N
		Compare match in GPT0.GTADTRA, or compare match in GPT0.GTADTRB	GTADTRA0N or GTADTRB0N	GTADTRA0N or GTADTRB0N
		Compare match in GPT1.GTADTRA, or compare match in GPT1.GTADTRB	GTADTRA1N or GTADTRB1N	GTADTRA1N or GTADTRB1N
		Compare match in GPT2.GTADTRA, or compare match in GPT2.GTADTRB	GTADTRA2N or GTADTRB2N	GTADTRA2N or GTADTRB2N
		Compare match in GPT3.GTADTRA, or compare match in GPT3.GTADTRB	GTADTRA3N or GTADTRB3N	GTADTRA3N or GTADTRB3N
Independent sample-and-hold function dedicated for channel	Target channel		AN000 to AN002	AN100 to AN102
Programmable gain amplifier	Target channel		AN000 to AN002	AN100 to AN102
	Gain setting		×2.0, ×2.5, ×3.077, ×3.636, ×4.0, ×4.444, ×5.0, ×5.714, ×6.667, ×10.0, ×13.333 (11 steps in total)	
Window comparator	Target channel		AN000 to AN002	AN100 to AN102
	Reference voltage setting	Specified through external pin	CVREFL: AN003, CVREFH: AN103	
		Internal generation	1/8AVCC0, 2/8AVCC0, 3/8AVCC0, 4/8AVCC0, 5/8AVCC0, 6/8AVCC0, 7/8AVCC0	
	Noise canceling function		Comparator detection results are sampled 16 times with PCLK, PCLK/2, PCLK/4, PCLK/8, PCLK/ 16, or PCLK/ 128	
Interrupt			S12ADI0 and CMPI	S12ADI1 and CMPI
Module stop function setting*			MSTPCRA. MSTPA17 bit	MSTPCRA. MSTPA16 bit

Note 1. For details, see section 9, Low Power Consumption.

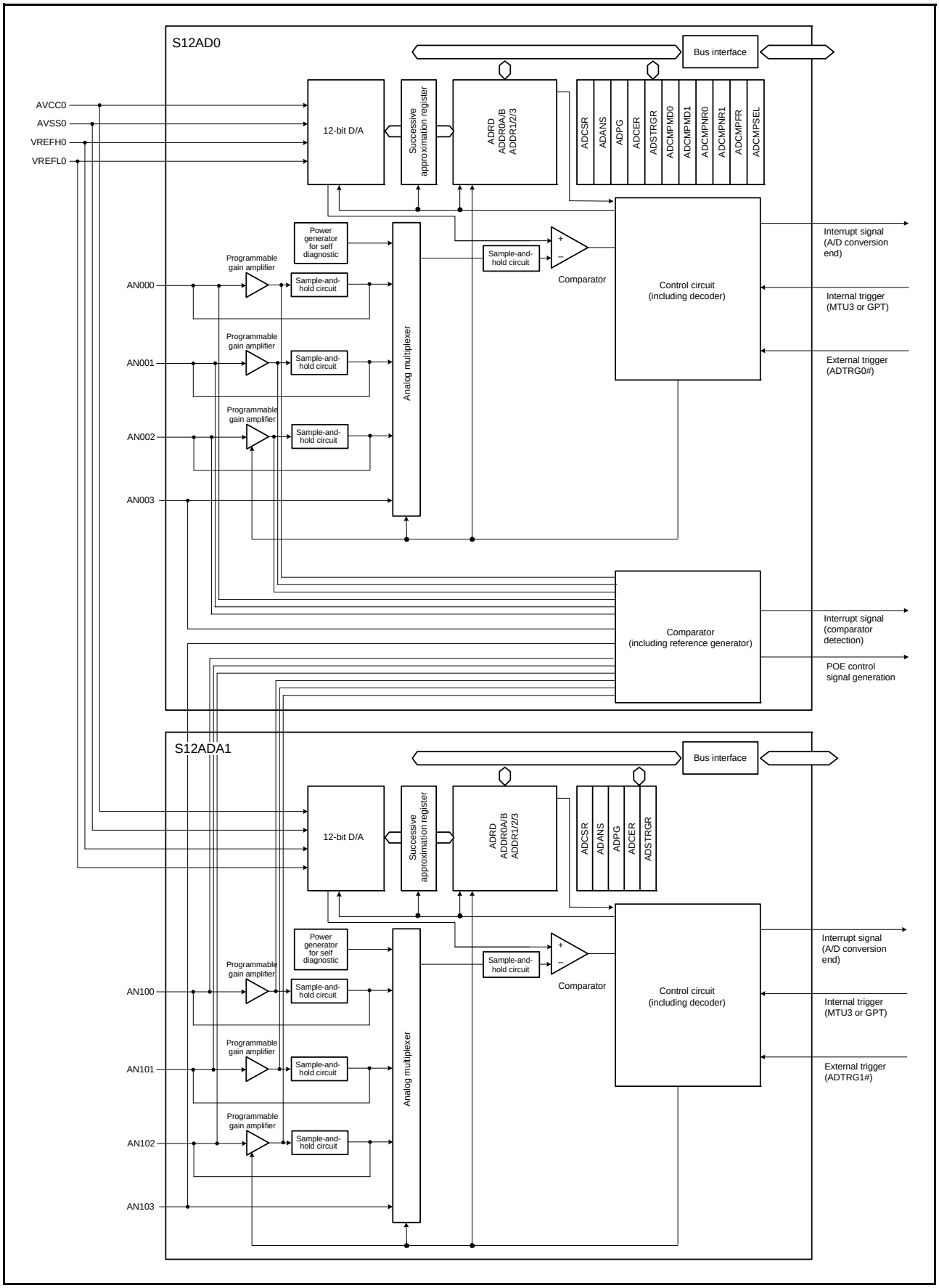


Figure 28.1 Block Diagram of A/D Converter

Table 28.3 indicates the input pins of the 12-bit A/D converter.
The 12-bit A/D converter has two units; unit 0 (S12AD0) and unit 1 (S12AD1) can be operated separately. The input channels for S12AD0 and S12AD1 can be operated separately in two groups. Programmable gain amplifiers (PGA) and comparators are provided for AN000 to AN002 and AN100 to AN102.

Table 28.3 Input Pins of A/D Converter

Unit	Pin Name	I/O	Function	Internal PGA	Internal Comparator
Unit 0 (S12AD0)	AN000	Input	Analog input pin 0	Provided	Provided
	AN001	Input	Analog input pin 1	Provided	Provided
	AN002	Input	Analog input pin 2	Provided	Provided
	AN003/CVREFL	Input	Analog input pin 3/comparator low reference voltage pin (works as the comparator low reference voltage pin when the comparator operation is enabled and reference voltage application through the external pin is selected)	—	—
	ADTRG0#	Input	External trigger input pin for starting A/D conversion	—	—
Unit 1 (S12AD1)	AN100	Input	Analog input pin 4	Provided	Provided
	AN101	Input	Analog input pin 5	Provided	Provided
	AN102	Input	Analog input pin 6	Provided	Provided
	AN103/CVREFH	Input	Analog input pin 7/comparator high reference voltage pin (works as the comparator high reference voltage pin when the comparator operation is enabled and reference voltage application through the external pin is selected)	—	—
	ADTRG1#	Input	External trigger input pin for starting A/D conversion	—	—
Common	AVCC0	Input	Analog block power supply pin	—	—
	AVSS0	Input	Analog block ground pin	—	—
	VREFH0	Input	Analog reference power supply pin for A/D converter	—	—
	VREFL0	Input	Analog reference ground pin for A/D converter	—	—

Note: • Each pin is connected to either of two units. Each unit has its own control registers, so be sure to set up the necessary registers in both units.
If the internal PGA is in use, ensure that the analog input voltage is within the range given in Table 33.15, Programmable Gain Amp Characteristics, of section 33.4, A/D Conversion Characteristics.

28.2 Register Descriptions

Table 28.4 lists the registers of the A/D converter.

Table 28.4 Registers of 12-Bit A/D Converter

Unit	Module Symbol	Register Name	Register Symbol	Value after Reset	Address	Access Size
0	S12AD0	A/D control register	ADCSR	00h	0008 9000h	8
		A/D channel select register	ADANS	0000h	0008 9004h	16
		A/D programmable gain amplifier register	ADPG	0000h	0008 900Ah	16
		A/D control extended register	ADCER	0000h	0008 900Eh	16
		A/D start trigger select register	ADSTRGR	0000h	0008 9010h	16
		A/D data register Diag	ADRD	0000h	0008 901Eh	16
		A/D data register 0A	ADDR0A	0000h	0008 9020h	16
		A/D data register 1	ADDR1	0000h	0008 9022h	16
		A/D data register 2	ADDR2	0000h	0008 9024h	16
		A/D data register 3	ADDR3	0000h	0008 9026h	16
		A/D data register 0B	ADDR0B	0000h	0008 9030h	16
		A/D sampling state register	ADSSTR	14h	0008 9060h	8
1	S12AD1	A/D control register	ADCSR	00h	0008 9080h	8
		A/D channel select register	ADANS	0000h	0008 9084h	16
		A/D programmable gain amplifier register	ADPG	0000h	0008 908Ah	16
		A/D control extended register	ADCER	0000h	0008 908Eh	16
		A/D start trigger select register	ADSTRGR	0000h	0008 9090h	16
		A/D data register Diag	ADRD	0000h	0008 909Eh	16
		A/D data register 0A	ADDR0A	0000h	0008 90A0h	16
		A/D data register 1	ADDR1	0000h	0008 90A2h	16
		A/D data register 2	ADDR2	0000h	0008 90A4h	16
		A/D data register 3	ADDR3	0000h	0008 90A6h	16
		A/D data register 0B	ADDR0B	0000h	0008 90B0h	16
		A/D sampling state register	ADSSTR	14h	0008 90E0h	8
Common	S12AD	Comparator operating mode select register 0	ADCMPMD0	0000h	0008 9012h	16
		Comparator operating mode select register 1	ADCMPMD1	0000h	0008 9014h	16
		Comparator filter mode register 0	ADCMPNR0	0000h	0008 9016h	16
		Comparator filter mode register 1	ADCMPNR1	0000h	0008 9018h	16
		Comparator detection flag register	ADCMPFR	00h	0008 901Ah	8
		Comparator interrupt select register	ADCMPSEL	0000h	0008 901Ch	16

28.2.1 A/D Data Registers n (ADDRn) (n = 0A, 0B, and 1 to 3) and A/D Data register Diag (ADRD)

ADDRn is a 16-bit read-only register that stores the A/D conversion results. Two data registers (double data registers) are provided each for AN000 and AN100 to store conversion results for two triggers separately when the conversion startup source is set to "TRGnAN or TRGnBN (n = 4 or 7) in the MTU3" or "GTADTRAnN or GTADTRBnN (n = 0 to 3) in the GPT". Table 28.5 shows the correspondence between analog input channels and ADDRn registers.
A/D data register Diag (ADRD) is a 16-bit read-only register that stores the A/D converted results for self diagnostic.
ADDRn and ADRD use different formats under the following conditions.

- Setting of A/D data register format select bit (right-alignment or left-alignment)
- Setting of A/D data register bit precision bits (12 bits, 10 bits, or 8 bits)

(1) ADDRn (n = 0A, 0B, and 1 to 3)

The ADCER.ADRFMT bit can be used to specify either right- or left-alignment. The ADCER.ADPRC[1:0] bit settings can be used to specify the bit precision for data storage. ADDRn.AD11 to AD0 bits indicate the 12-bit A/D-converted value. The other bits are reserved. The reserved bits are always read as 0 and the write value should always be 0.

- When right-alignment with 12-bit precision is selected

Address: S12AD0.ADDR0A 0008 9020h, S12AD0.ADDR1 0008 9022h, S12AD0.ADDR2 0008 9024h, S12AD0.ADDR3 0008 9026h, S12AD0.ADDR0B 0008 9030h
S12AD1.ADDR0A 0008 90A0h, S12AD1.ADDR1 0008 90A2h, S12AD1.ADDR2 0008 90A4h, S12AD1.ADDR3 0008 90A6h, S12AD1.ADDR0B 0008 90B0h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	AD11	AD10	AD9	AD8	AD7	AD6	AD5	AD4	AD3	AD2	AD1	AD0
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b11 to b0	AD11 to AD0	A/D Converted Value 11 to 0	12-bit A/D-converted value	R
b15 to b12	—	Reserved	These bits are always read as 0. Writing 0 to these bits has no effect.	R

- When right-alignment with 10-bit precision is selected

Address: S12AD0.ADDR0A 0008 9020h, S12AD0.ADDR1 0008 9022h, S12AD0.ADDR2 0008 9024h, S12AD0.ADDR3 0008 9026h, S12AD0.ADDR0B 0008 9030h
S12AD1.ADDR0A 0008 90A0h, S12AD1.ADDR1 0008 90A2h, S12AD1.ADDR2 0008 90A4h, S12AD1.ADDR3 0008 90A6h, S12AD1.ADDR0B 0008 90B0h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	AD11	AD10	AD9	AD8	AD7	AD6	AD5	AD4	AD3	AD2
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b9 to b0	AD11 to AD2	A/D Converted Value 11 to 2	Upper ten bits of 12-bit A/D-converted value	R
b15 to b10	—	Reserved	These bits are always read as 0. Writing 0 to these bits has no effect.	R

- When right-alignment with 8-bit precision is selected

Address: S12AD0.ADDRA0 0008 9020h, S12AD0.ADDRB 0008 9022h, S12AD0.ADDRC 0008 9024h, S12AD0.ADDRD 0008 9026h, S12AD0.ADDRA1 0008 9030h
S12AD1.ADDRA0 0008 90A0h, S12AD1.ADDRB 0008 90A2h, S12AD1.ADDRC 0008 90A4h, S12AD1.ADDRD 0008 90A6h, S12AD1.ADDRA1 0008 90B0h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	AD11	AD10	AD9	AD8	AD7	AD6	AD5	AD4
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b7 to b0	AD11 to AD4	A/D Converted Value 11 to 4	Upper eight bits of 12-bit A/D-converted value	R
b15 to b8	—	Reserved	These bits are always read as 0. Writing 0 to these bits has no effect.	R

- When left-alignment with 12-bit precision is selected

Address: S12AD0.ADDR0A 0008 9020h, S12AD0.ADDR1 0008 9022h, S12AD0.ADDR2 0008 9024h, S12AD0.ADDR3 0008 9026h, S12AD0.ADDR0B 0008 9030h
S12AD1.ADDR0A 0008 90A0h, S12AD1.ADDR1 0008 90A2h, S12AD1.ADDR2 0008 90A4h, S12AD1.ADDR3 0008 90A6h, S12AD1.ADDR0B 0008 90B0h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	AD11	AD10	AD9	AD8	AD7	AD6	AD5	AD4	AD3	AD2	AD1	AD0	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b3 to b0	—	Reserved	These bits are always read as 0. Writing 0 to these bits has no effect.	R
b15 to b4	AD11 to AD0	A/D Converted Value 11 to 0	12-bit A/D-converted value	R

- When left-alignment with 10-bit precision is selected

Address: S12AD0.ADDR0A 0008 9020h, S12AD0.ADDR1 0008 9022h, S12AD0.ADDR2 0008 9024h, S12AD0.ADDR3 0008 9026h, S12AD0.ADDR0B 0008 9030h
S12AD1.ADDR0A 0008 90A0h, S12ADS12AD1.ADDR1 0008 90A2h, S12AD1.ADDR2 0008 90A4h, S12AD1.ADDR3 0008 90A6h, S12AD1.ADDR0B 0008 90B0h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	AD11	AD10	AD9	AD8	AD7	AD6	AD5	AD4	AD3	AD2	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b5 to b0	—	Reserved	These bits are always read as 0. Writing 0 to these bits has no effect.	R
b15 to b6	AD11 to AD2	A/D Converted Value 11 to 2	Upper ten bits of 12-bit A/D-converted value	R

- When left-alignment with 8-bit precision is selected

Address: S12AD0.ADDR0A 0008 9020h, S12AD0.ADDR1 0008 9022h, S12AD0.ADDR2 0008 9024h, S12AD0.ADDR3 0008 9026h, S12AD0.ADDR0B 0008 9030h
S12AD1.ADDR0A 0008 90A0h, S12AD1.ADDR1 0008 90A2h, S12AD1.ADDR2 0008 90A4h, S12AD1.ADDR3 0008 90A6h, S12AD1.ADDR0B 0008 90B0h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	AD11	AD10	AD9	AD8	AD7	AD6	AD5	AD4	—	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b7 to b0	—	Reserved	These bits are always read as 0. Writing 0 to these bits has no effect.	R
b15 to b8	AD11 to AD4	A/D Converted Value 11 to 4	Upper eight bits of 12-bit A/D-converted value	R

(2) ADRD

The ADCER.ADRFMT bit can be used to specify either right- or left-alignment. The AD11 to AD0 bits indicate a 12-bit A/D-converted value. Self diagnostic status (ADRD.DIAGST[1:0]) bits are also included. The other bits are reserved. The reserved bits are always read as 0 and writing 0 to these bits has no effect.

- When right-alignment is selected

Address: S12AD0.ADRD 0008 901Eh, S12AD1.ADRA 0008 909Eh

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	DISGST[1:0]		—	—	AD11	AD10	AD9	AD8	AD7	AD6	AD5	AD4	AD3	AD2	AD1	AD0
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b11 to b0	AD11 to AD0	A/D Converted Value 11 to 0	12-bit A/D-converted value	R
b13, b12	—	Reserved	These bits are always read as 0. Writing 0 to these bits has no effect.	R
b15, b14	DIAGST [1:0]	Self Diagnostic Status	b15 b14 0 0:No self diagnostic has ever been performed since power-on. 0 1:Self diagnostic has been performed at a voltage of VREFH0 × 0. 1 0:Self diagnostic has been performed at a voltage of VREFH0 × 1/2. 1 1:Self diagnostic has been performed at a voltage of VREFH0 × 1. Note: • For details on self diagnostic, see section 28.2.4, A/D Control Extended Register (ADCER).	R

- When left-alignment is selected

Address: S12AD0.ADRD 0008 901Eh, S12AD1.ADRD 0008 909Eh

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	AD11	AD10	AD9	AD8	AD7	AD6	AD5	AD4	AD3	AD2	AD1	AD0	—	—	DISGST[1:0]	
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1, b0	DIAGST [1:0]	Self Diagnostic Status	b1 b0 0 0:No self diagnostic has ever been performed since power-on. 0 1:Self diagnostic has been performed at a voltage of VREFH0 × 0. 1 0:Self diagnostic has been performed at a voltage of VREFH0 × 1/2. 1 1:Self diagnostic has been performed at a voltage of VREFH0 × 1. Note: • For details on self diagnostic, section 28.2.4, A/D Control Extended Register (ADCER).	R
b3, b2	—	Reserved	These bits are always read as 0. Writing 0 to these bits has no effect.	R
b15 to b4	AD11 to AD0	A/D Converted Value 11 to 0	12-bit A/D-converted value	R

Table 28.5 Analog Input Channels and Corresponding ADDRn Registers

Analog Input Channel	ADDRn Register
AN000	S12AD0.ADDR0A and S12AD0.ADDR0B *
AN001	S12AD0.ADDR1
AN002	S12AD0.ADDR2
AN003	S12AD0.ADDR3
AN100	S12AD1.ADDR0A and S12AD1.ADDR0B *
AN101	S12AD1.ADDR1
AN102	S12AD1.ADDR2
AN103	S12AD1.ADDR3

Note 1. • When the A/D conversion startup source is neither "TRGnAN or TRGnBN (n = 4 or 7) in the MTU3" nor "GTADTRAnN or GTADTRBnN (n = 0 to 3) in the GPT" (ADSTRGR.ADSTRSn[4:0] bit are not 01011b, 01111b, or 11001b to 11100b), the conversion result is stored in ADDR0A.

Note 2. • When the A/D conversion startup source is "TRGnAN or TRGnBN (n = 4 or 7) in the MTU3" (ADSTRGR.ADSTRSn[4:0] bits are set to 01011b or 01111b), the result of conversion started by TRGnAN is stored in ADDR0A and that started by TRGnBN is stored in ADDR0B.

Note 3. • When the A/D conversion startup source is "GTADTRAnN or GTADTRBnN (n = 0 to 3) in the GPT" (ADSTRGR.ADSTRSn[4:0] bits are set to 11001b to 11100b), the result of conversion started by GTADTRAnN is stored in ADDR0A and that started by GTADTRBnN is stored in ADDR0B.

28.2.2 A/D Control Register (ADCSR)

Address: S12AD0.ADCSR 0008 9000h, S12AD1.ADCSR 0008 9080h

	b7	b6	b5	b4	b3	b2	b1	b0
	ADST	ADCS[1:0]		ADIE	CKS[1:0]		TRGE	EXTRG
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	EXTRG	Trigger Select	0: A/D conversion is started by a timer source selected by the A/D start trigger select register (ADSTRGR). 1: A/D conversion is started by an external trigger (ADTRGn#). (n = 0 or 1)	R/W
b1	TRGE	Trigger Enable	0: Disables A/D conversion to be started by an external trigger (ADTRGn#) or a trigger from MTU3 or GPT. 1: Enables A/D conversion to be started by an external trigger (ADTRGn#) or a trigger from MTU3 or GPT. (n = 0 or 1)	R/W
b3, b2	CKS[1:0]	Clock Select	b3 b2 0 0: PCLK/8 0 1: PCLK/4 1 0: PCLK/2 1 1: PCLK	R/W
b4	ADIE	A/D Conversion End Interrupt Enable	0: Disables S12ADI interrupt generation upon A/D conversion completion. 1: Enables S12ADI interrupt generation upon A/D conversion completion.	R/W
b6, b5	ADCS[1:0]	A/D Conversion Mode Select	b6 b5 0 0:Single mode 0 1:Single-cycle scan mode 1 0:Continuous scan mode 1 1:2-channel scan mode	R/W
b7	ADST	A/D Start	0: Stops an A/D conversion process. 1: Starts an A/D conversion process.	R/W

Note: Starting an A/D conversion using an external trigger
If 1 is written to both the TRGE and EXTRG bits when a high-level signal is input to the external trigger pin (ADTRGn#), and then if the ADTRGn# signal is driven low, the falling edge of ADTRGn# is detected and the A/D conversion process started.
In this case, the pulse width of the low-level input must be at least 1.5 PCLK clock cycles. (n = 0 or 1)

ADCSR selects the clock and performs the settings for A/D conversion start/stop, A/D conversion mode, and A/D conversion trigger. The ADCS[1:0] and CKS[1:0] bits should be set while the ADST bit is 0.

CKS[1:0] Bits (Clock Select)

These bits set the frequency of the A/D conversion clock (ADCLK) and thus select the A/D conversion time.
Set the frequency of ADCLK above 4 MHz. When AVCC0 is in the range from 3.0 V to 3.6 V, set the frequency of ADCLK below 25 MHz.
For details, see section 28.3.3, Analog Input Sampling and A/D Conversion Time.

ADIE Bit (A/D Conversion End Interrupt Enable)

The ADIE bit enables or disables the A/D conversion end interrupt (S12ADI).
When A/D conversion of the specified channels is completed while the ADIE bit is set to 1, an A/D conversion end interrupt (S12ADI) is generated.

ADCS[1:0] Bits (A/D Conversion Mode Select)

The ADCS bits select the A/D conversion mode.
In single mode, A/D conversion of the analog input from the single channel specified by the ADANS.CH[1:0] bits is performed only once.
In single-cycle scan mode, A/D conversion of the analog inputs from up to four channels specified by the ADANS.CH[1:0] bits is performed in the ascending order of channel numbers only once, and when A/D conversion of all selected channels is completed, A/D conversion stops.
In continuous scan mode, while the ADCSR.ADST bit is 1, A/D conversion of the analog inputs from up to four channels specified by the ADANS.CH[1:0] bits is performed in the ascending order of channel numbers, and when A/D conversion of all selected channels is completed, A/D conversion returns to the first channel and repeats A/D conversion. A/D conversion stops when the ADCSR.ADST bit is cleared to 0.
In 2-channel scan mode, four channels of analog inputs are separated into two groups and the start trigger can be separately selected for each group. A/D conversion of the analog inputs from up to three channels specified by the ADANS.CH[1:0] bits is performed in the ascending order of channel numbers only once, and when A/D conversion of all selected channels is completed, A/D conversion stops.

ADST Bit (A/D Start)

This bit starts or stops an A/D conversion process. Before the ADST bit is set to 1, set the A/D conversion clock and operating mode.
[Setting conditions]

- When 1 is written by software
- When the TRGE bit is set to 1, the EXTRG bit is cleared to 0, and the MTU3 or GPT trigger selected by the ADSTRGR.ADSTRSn[4:0] bits is detected
- When the TRGE and EXTRG bits are set to 1, the ADSTRGR.ADSTRSn[4:0] bits are set to 00000b, and an external trigger is detected

[Clearing conditions]

- When 0 is written by software
- When A/D conversion is completed in single mode
- When A/D conversion of all selected channels is completed in single-cycle scan mode
- When A/D conversion of all selected channels in each group is completed in 2-channel scan mode

28.2.3 A/D Channel Select Register (ADANS)

(1) S12AD0.ADANS

Address: 0008 9004h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	CH[1:0]		—	PG002 SEL	PG001 SEL	PG000 SEL	—	—	—	—	—	PG002 EN	PG001 EN	PG000 EN
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	PG000EN	AN000 Programmable Gain Amplifier Enable	0: Programmable gain amplifier disabled 1: Programmable gain amplifier enabled	R/W
b1	PG001EN	AN001 Programmable Gain Amplifier Enable	0: Programmable gain amplifier disabled 1: Programmable gain amplifier enabled	R/W
b2	PG002EN	AN002 Programmable Gain Amplifier Enable	0: Programmable gain amplifier disabled 1: Programmable gain amplifier enabled	R/W
b7 to b3	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b8	PG000SEL	AN000 Programmable Gain Amplifier Select	0: Programmable gain amplifier not used (bypassed) 1: Programmable gain amplifier used	R/W
b9	PG001SEL	AN001 Programmable Gain Amplifier Select	0: Programmable gain amplifier not used (bypassed) 1: Programmable gain amplifier used	R/W
b10	PG002SEL	AN002 Programmable Gain Amplifier Select	0: Programmable gain amplifier not used (bypassed) 1: Programmable gain amplifier used	R/W
b11	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b13, b12	CH[1:0]	Channel Set	These bits select the analog input channels to be A/D-converted in S12AD0. For details, see Table 28.6	R/W
b15, b14	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

(2) S12AD1.ADANS

Address: 0008 9084h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	CH[1:0]		—	PG102 SEL	PG101 SEL	PG100 SEL	—	—	—	—	—	PG102 EN	PG101 EN	PG100 EN
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	PG100EN	AN100 Programmable Gain Amplifier Enable	0: Programmable gain amplifier disabled 1: Programmable gain amplifier enabled	R/W
b1	PG101EN	AN101 Programmable Gain Amplifier Enable	0: Programmable gain amplifier disabled 1: Programmable gain amplifier enabled	R/W
b2	PG102EN	AN102 Programmable Gain Amplifier Enable	0: Programmable gain amplifier disabled 1: Programmable gain amplifier enabled	R/W
b7 to b3	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b8	PG100SEL	AN100 Programmable Gain Amplifier Select	0: Programmable gain amplifier not used (bypassed) 1: Programmable gain amplifier used	R/W
b9	PG101SEL	AN101 Programmable Gain Amplifier Select	0: Programmable gain amplifier not used (bypassed) 1: Programmable gain amplifier used	R/W
b10	PG102SEL	AN102 Programmable Gain Amplifier Select	0: Programmable gain amplifier not used (bypassed) 1: Programmable gain amplifier used	R/W
b11	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b13, b12	CH[1:0]	Channel Set	These bits select the analog input channels to be A/D-converted in S12AD0. For details, see Table 28.6	R/W
b15, b14	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

ADANS is a register that selects the channels that are subject to A/D conversion and specifies whether to enable and use the programmable gain amplifiers for AN000 to AN002 and AN100 and AN102.
Note that ADANS should be specified only while the ADCSR.ADST bit is 0.

PGnEN Bit (ANn Programmable Gain Amplifier Enable) (n = 000 to 002 and 100 to 102)

The PGnEN bit enables or disables the programmable gain amplifier.

PGnSEL Bit (ANn Programmable Gain Amplifier Select) (n = 000 to 002 and 100 to 102)

The PGnSEL bit specifies whether to use the programmable gain amplifier.

CH[1:0] Bits (Channel Set)

The CH[1:0] bits specify the channels subject to A/D conversion. This setting depends on the ADCSR.ADCS[1:0] bit setting. For details, refer to Table 28.6.

Table 28.6 Conversion Channel Settings

		Analog Input Channel			
ADANS.CH[1:0]		Single Mode		Single-Cycle Scan Mode/Continuous Scan Mode	
b1	b0	S12AD0	S12AD1	S12AD0	S12AD1
0	0	AN000	AN100	AN000	AN100
0	1	AN001	AN101	AN000, AN001	AN100, AN101
1	0	AN002	AN102	AN000 to AN002	AN100 to AN102
1	1	AN003	AN103	AN000 to AN003	AN100 to AN103

		Analog Input Channel	
ADANS.CH[1:0]		2-Channel Scan Mode (Started by Timer Trigger or External Trigger)	
b1	b0	S12AD0	S12AD1
0	0	Group 0: AN000 Group 1: AN001 to AN003	Group 0: AN100 Group 1: AN101 to AN103
0	1	Group 0: AN000, AN001 Group 1: AN002, AN003	Group 0: AN100, AN101 Group 1: AN102, AN103
1	0	Group 0: AN000 to AN002 Group 1: AN003	Group 0: AN100 to AN102 Group 1: AN103
1	1	Setting prohibited (same operation as 00b)	Setting prohibited (same operation as 00b)

		Analog Input Channel	
ADANS.CH[1:0]		2-Channel Scan Mode (Started by Software)	
b1	b0	S12AD0	S12AD1
0	0	AN000	AN100
0	1	AN000, AN001	AN100, AN101
1	0	AN000 to AN002	AN100 to AN102
1	1	AN000 to AN003	AN100 to AN103

28.2.4 A/D Control Extended Register (ADCER)

Address: S12AD0.ADCER 0008 900Eh, S12AD1.ADCER 0008 908Eh

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	ADRFMT	—	ADIEW	ADIE2	DIAGM	DIAGLD	DIAGVAL[1:0]		—	—	ACE	—	—	ADPRC[1:0]		SHBYP
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	SHBYP	Dedicated Sample-and-Hold Circuit Select	0: Sample-and-hold circuit used 1: Sample-and-hold circuit not used	R/W
b2, b1	ADPRC[1:0]	A/D Data Register Bit Precision Set	0 0: Stored in A/D data register with 12-bit precision 0 1: Stored in A/D data register with 10-bit precision 1 0: Stored in A/D data register with 8-bit precision 1 1: Setting prohibited (Stored with 12-bit precision)	R/W
b4, b3	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b5	ACE	Automatic Clearing Enable	0: Disables automatic clearing of ADDRn and ADRD after they have been read. 1: Enables automatic clearing of ADDRn and ADRD after they have been read.	R/W
b7, b6	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b9, b8	DIAGVAL[1:0]	Self Diagnostic Voltage Select	b9 b8 0 0: Setting prohibited 0 1: Self diagnostic at a voltage of VREFH0 × 0 1 0: Self diagnostic at a voltage of VREFH0 × 1/2 1 1: Self diagnostic at a voltage of VREFH0 × 1	R/W
b10	DIAGLD	Self Diagnostic Mode Select	0: Self diagnostic voltages are automatically rotated 1: Self diagnostic voltage is fixed to the DIAGVAL[1:0] bit setting	R/W
b11	DIAGM	Self Diagnostic Enable	0: Self diagnostic of the A/D converter is not performed 1: Self diagnostic of the A/D converter is performed	R/W
b12	ADIE2	2-Channel Scan Interrupt Select	0: S12ADI interrupt is generated every time a conversion process started by either of group 0 and 1 triggers is completed 1: S12ADI interrupt is generated when the conversion processes started by group 0 and 1 triggers are both completed	R/W
b13	ADIEW	Double Trigger Interrupt Select	0: S12ADI interrupt is generated every time a conversion process started by either of the double triggers is completed 1: S12ADI interrupt is generate when the conversion processes started by the double triggers are both completed	R/W
b14	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b15	ADRFMT	A/D Data Register Format Select	0: Right-alignment is selected for the A/D data register format. 1: Left-alignment is selected for the A/D data register format.	R/W

ADCER sets the A/D data register format, self diagnostic mode, and automatic clearing of registers, and selects the sample-and-hold circuit dedicated for the channel and interrupt generation. The ADCER value should be changed only while the ADCSR.ADST bit is 0.

SHBYP Bit (Dedicated Sample-and-Hold Circuit Select)

The SHBYP bit selects whether to use the sample-and-hold circuit dedicated for the channel.

When a programmable gain amplifier is in use, set the SHBYP bit to 0 (selecting use of the sample-and-hold circuit).

ADPRC Bit (A/D Data Register Bit Precision Set)

The ADPRC bit selects the precision for storing A/D conversion results in the A/D data register from 8 bits, 10 bits, and 12 bits.

ACE Bit (Automatic Clearing Enable)

The ACE bit enables or disables automatic clearing of ADDRn or ADRD after it has been read by the CPU or DTC. This function enables update failures of ADDRn and ADRD to be detected.

DIAGVAL[1:0] Bits (Self Diagnostic Voltage Select)

For details of these bits, refer to the description of the DIAGLD bit. When the DIAGVAL[1:0] bits are set to 00b (setting prohibited) which is the initial value, do not start self diagnostic with the DIAGLD bit to set to 1.

DIAGLD Bit (Self Diagnostic Mode Select)

The DIAGLD bit selects whether to rotate among three voltages or use a fixed voltage for conversion in self diagnostic. When the DIAGLD bit is cleared to 0, three voltages are converted in turn, in the order of VREFH0 × 0 → VREFH0 × 1/2 → VREFH0 × 1. After a power-on reset, self diagnostic starts with VREFH0 × 0. Even when scan conversion is completed, the self-diagnostic voltage is not reset to VREFH0 × 0; when scan conversion is performed again, voltage rotation starts from where conversion is completed in the previous diagnostic.
When the DIAGLD bit is set to 1, the conversion voltage is fixed at that specified in the DIAGVAL[1:0] bits (automatic rotation is not done). When the DIAGLD bit is cleared to 0 again, rotation starts from the voltage fixed before (load function).

DIAGM Bit (Self Diagnostic Enable)

The self diagnostic function is used to detect faults in the A/D converter. One of three internally-generated voltages, VREFH0 × 0, VREFH0 × 1/2, and VREFH0 × 1, is converted.
After A/D conversion ends, the A/D-converted value and information on the converted voltage are stored in A/D data register Diag (ADRD). Then, whether the conversion result is within the normal range (normal) or not (error) can be found out from the values read from ADRD by software. Self diagnostic is performed before the smallest-numbered channel is converted in the scan conversion process.
In each execution of self diagnostic, one of the three voltages is converted, and the three voltages are automatically rotated each time self diagnostic is executed. The execution time required for self diagnostic is equal to the A/D conversion time for one channel.

ADIE2 Bit (2-Channel Scan Interrupt Select)

The ADIE2 bit selects the timing for generating an S12ADI interrupt in 2-channel scan mode. The ADIE2 bit setting is valid only when A/D conversion is started by a trigger (ADCSR.TRGE = 1) in 2-channel scan mode.

ADIEW Bit (Double Trigger Interrupt Select)

The ADIEW bit selects the timing for generating an S12ADI interrupt when double triggers are selected. The ADIEW bit setting is valid only when A/D conversion is started by a trigger (ADCSR.TRGE = 1) and the trigger source is set to "TRG4AN or TRG4BN", "TRG7AN or TRG7BN", "GTADTRA0N or GTADTRB0N", "GTADTRA1N or GTADTRB1N", "GTADTRA2N or GTADTRB2N", or "GTADTRA3N or GTADTRB3N".

ADRFMT Bit (A/D Data Register Format Select)

The ADRFMT bit specifies left-alignment or right-alignment for the data to be stored in the A/D data register.
For details on the format of the A/D data registers, see section 28.2.1, A/D Data Registers n (ADDRn) (n = 0A, 0B, and 1 to 3) and A/D Data register Diag (ADRD).

28.2.5 A/D Start Trigger Select Register (ADSTRGR)

Address: 12ADA0.ADSTRGR 0008 9010h, S12AD1.ADSTRGR 0008 9090h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	ADSTRS1[4:0]					—	—	—	ADSTRS0[4:0]				
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b4 to b0	ADSTRS0[4:0]	A/D Start Trigger Group 0 Select	The combination of bits 4 to 0 selects the source of requests to start A/D conversion from among various on-chip peripheral I/O sources and input on the trigger input pin. Specify the starting source for conversion in single mode, single-cycle scan mode, continuous scan mode or the starting source for group 0 when conversion is in two-channel scan mode. See Table 28.7 for the correspondence between the settings and starting sources.	R/W
b7, b5	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b12 to b8	ADSTRS1[4:0]	A/D Start Trigger Group 1 Select	These bits are only used in two-channel scan mode. The combination of bits 4 to 0 selects the source of requests to start A/D conversion from among various on-chip peripheral I/O sources and input on the trigger input pin. Specify the starting source for group 1 when conversion is in two-channel scan mode. See Table 28.7 for the correspondence between the settings and starting sources. In two-channel scan mode, specify different sources for requests to start conversion by group 0 and group 1 such that requests to start conversion by both groups are not generated at the same time.	R/W
b15 to b13	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

ADSTRGR selects the A/D conversion startup trigger.

The ADSTRGR value should be changed only while the ADCSR.ADST bit is 0.

- Software trigger (ADCSR.ADST bit) is always enabled regardless of the values set in the ADCSR.TRGE, ADCSR.EXTRG, and ADSTRGR register.
- When using an external input as the A/D conversion startup trigger (ADTRGn#), set the ADCSR.TRGE bit to 1 and the ADCSR.EXTRG bit to 1. (n = 0 or 1)
- When using the MTU3 or GPT as the A/D conversion startup source, set the ADCSR.TRGE bit to 1 and the ADCSR.EXTRG bit to 0.

Table 28.7 List of A/D Conversion Startup Sources

Module	A/D Conversion Startup Sources	Startup Condition	ADSTRSn [4]	ADSTRSn [3]	ADSTRSn [2]	ADSTRSn [1]	ADSTRSn [0]
Software	ADST	ADCSR.ADST bit is set	—	—	—	—	—
External pin	ADTRGn#	Trigger input pin	0	0	0	0	0
MTU3	TRGA0N	Compare match/input capture in MTU0.TGRA	0	0	0	0	1
	TRGA1N	Compare match/input capture in MTU1.TGRA	0	0	0	1	0
	TRGA2N	Compare match/input capture in MTU2.TGRA	0	0	0	1	1
	TRGA3N	Compare match/input capture in MTU3.TGRA	0	0	1	0	0
	TRGA4N	Compare match/input capture in MTU4.TGRA, or MTU4.TCNT underflow in complementary PWM mode (trough)	0	0	1	0	1
	TRGA6N	Compare match/input capture in MTU6.TGRA	0	0	1	1	0
	TRGA7N	Compare match/input capture in MTU7.TGRA, or MTU7.TCNT underflow in complementary PWM mode (trough)	0	0	1	1	1
	TRG0N	Compare match in MTU0.TGRE	0	1	0	0	0
	TRG4AN	Compare match between MTU4.TADCORA and MTU4.TCNT	0	1	0	0	1
	TRG4BN	Compare match between MTU4.TADCORB and MTU4.TCNT	0	1	0	1	0
	TRG4AN or TRG4BN	Compare match between MTU4.TADCORA and MTU4.TCNT or compare match between MTU4.TADCORB and MTU4.TCNT	0	1	0	1	1
	TRG4ABN	Compare match between MTU4.TADCORA and MTU4.TCNT and compare match between MTU4.TADCORB and MTU4.TCNT (when interrupt skipping function 2 is used)	0	1	1	0	0
	TRG7AN	Compare match between MTU7.TADCORA and MTU7.TCNT	0	1	1	0	1
	TRG7BN	Compare match between MTU7.TADCORB and MTU7.TCNT	0	1	1	1	0
	TRG7AN or TRG7BN	Compare match between MTU7.TADCORA and MTU7.TCNT or compare match between MTU7.TADCORB and MTU7.TCNT	0	1	1	1	1
	TRG7ABN	Compare match between MTU7.TADCORA and MTU7.TCNT and compare match between MTU7.TADCORB and MTU7.TCNT (when interrupt skipping function 2 is used)	1	0	0	0	0

Table 28.7 List of A/D Conversion Startup Sources

Module	A/D Conversion Startup Sources	Startup Condition	ADSTRSn [4]	ADSTRSn [3]	ADSTRSn [2]	ADSTRSn [1]	ADSTRSn [0]
GPT	GTADTRA0N	Compare match in GPT0.GTADTRA	1	0	0	0	1
	GTADTRB0N	Compare match in GPT0.GTADTRB	1	0	0	1	0
	GTADTRA1N	Compare match in GPT1.GTADTRA	1	0	0	1	1
	GTADTRB1N	Compare match in GPT1.GTADTRB	1	0	1	0	0
	GTADTRA2N	Compare match in GPT2.GTADTRA	1	0	1	0	1
	GTADTRB2N	Compare match in GPT2.GTADTRB	1	0	1	1	0
	GTADTRA3N	Compare match in GPT3.GTADTRA	1	0	1	1	1
	GTADTRB3N	Compare match in GPT3.GTADTRB	1	1	0	0	0
	GTADTRA0N or GTADTRB0N	Compare match in GPT0.GTADTRA or compare match in GPT0.GTADTRB	1	1	0	0	1
	GTADTRA1N or GTADTRB1N	Compare match in GPT1.GTADTRA or compare match in GPT1.GTADTRB	1	1	0	1	0
	GTADTRA2N or GTADTRB2N	Compare match in GPT2.GTADTRA or compare match in GPT2.GTADTRB	1	1	0	1	1
	GTADTRA3N or GTADTRB3N	Compare match in GPT3.GTADTRA or compare match in GPT3.GTADTRB	1	1	1	0	0

Note: • When ADTRGn# is used as the A/D conversion trigger, the PORTn.DDR.Bj bit and PORTn.ICR.Bj bit corresponding to the pin should be set to 0 (input port) and 1 (the input buffer of the corresponding pin enabled), respectively. For details, refer to section 15, I/O Ports.

28.2.6 A/D Programmable Gain Amplifier Register (ADPG)

(1) S12AD0.ADPG

Address: 0008 900Ah

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	PG002GAIN[3:0]				PG001GAIN[3:0]				PG000GAIN[3:0]			
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b3 to b0	PG000GAIN[3:0]	Gain Select for AN000 Programmable Gain Amplifier	b3 b0 0 0 0 0: ×2.0 0 0 0 1: ×2.5 0 0 1 0: Setting prohibited 0 0 1 1: Setting prohibited 0 1 0 0: ×3.077 0 1 0 1: Setting prohibited 0 1 1 0: ×3.636 0 1 1 1: ×4.0 1 0 0 0: ×4.444 1 0 0 1: ×5.0 1 0 1 0: ×5.714 1 0 1 1: ×6.667 1 1 0 0: Setting prohibited 1 1 0 1: ×10.0 1 1 1 0: ×13.333 1 1 1 1: Setting prohibited	R/W
b7 to b4	PG001GAIN[3:0]	Gain Select for AN001 Programmable Gain Amplifier	b7 b4 0 0 0 0: ×2.0 0 0 0 1: ×2.5 0 0 1 0: Setting prohibited 0 0 1 1: Setting prohibited 0 1 0 0: ×3.077 0 1 0 1: Setting prohibited 0 1 1 0: ×3.636 0 1 1 1: ×4.0 1 0 0 0: ×4.444 1 0 0 1: ×5.0 1 0 1 0: ×5.714 1 0 1 1: ×6.667 1 1 0 0: Setting prohibited 1 1 0 1: ×10.0 1 1 1 0: ×13.333 1 1 1 1: Setting prohibited	R/W
b11 to b8	PG002GAIN[3:0]	Gain Select for AN002 Programmable Gain Amplifier	b11 b8 0 0 0 0: ×2.0 0 0 0 1: ×2.5 0 0 1 0: Setting prohibited 0 0 1 1: Setting prohibited 0 1 0 0: ×3.077 0 1 0 1: Setting prohibited 0 1 1 0: ×3.636 0 1 1 1: ×4.0 1 0 0 0: ×4.444 1 0 0 1: ×5.0 1 0 1 0: ×5.714 1 0 1 1: ×6.667 1 1 0 0: Setting prohibited 1 1 0 1: ×10.0 1 1 1 0: ×13.333 1 1 1 1: Setting prohibited	R/W

Bit	Symbol	Bit Name	Description	R/W
b15 to b12	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

(2) S12AD1.ADPG

Address: 0008 908Ah

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	PG102GAIN[3:0]				PG101GAIN[3:0]				PG100GAIN[3:0]			
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b3 to b0	PG100GAIN[3:0]	Gain Select for AN100 Programmable Gain Amplifier	b3 b0 0 0 0 0: ×2.0 0 0 0 1: ×2.5 0 0 1 0: Setting prohibited 0 0 1 1: Setting prohibited 0 1 0 0: ×3.077 0 1 0 1: Setting prohibited 0 1 1 0: ×3.636 0 1 1 1: ×4.0 1 0 0 0: ×4.444 1 0 0 1: ×5.0 1 0 1 0: ×5.714 1 0 1 1: ×6.667 1 1 0 0: Setting prohibited 1 1 0 1: ×10.0 1 1 1 0: ×13.333 1 1 1 1: Setting prohibited	R/W
b7 to b4	PG101GAIN[3:0]	Gain Select for AN101 Programmable Gain Amplifier	b7 b4 0 0 0 0: ×2.0 0 0 0 1: ×2.5 0 0 1 0: Setting prohibited 0 0 1 1: Setting prohibited 0 1 0 0: ×3.077 0 1 0 1: Setting prohibited 0 1 1 0: ×3.636 0 1 1 1: ×4.0 1 0 0 0: ×4.444 1 0 0 1: ×5.0 1 0 1 0: ×5.714 1 0 1 1: ×6.667 1 1 0 0: Setting prohibited 1 1 0 1: ×10.0 1 1 1 0: ×13.333 1 1 1 1: Setting prohibited	R/W
b11 to b8	PG102GAIN[3:0]	Gain Select for AN102 Programmable Gain Amplifier	b11 b8 0 0 0 0: ×2.0 0 0 0 1: ×2.5 0 0 1 0: Setting prohibited 0 0 1 1: Setting prohibited 0 1 0 0: ×3.077 0 1 0 1: Setting prohibited 0 1 1 0: ×3.636 0 1 1 1: ×4.0 1 0 0 0: ×4.444 1 0 0 1: ×5.0 1 0 1 0: ×5.714 1 0 1 1: ×6.667 1 1 0 0: Setting prohibited 1 1 0 1: ×10.0 1 1 1 0: ×13.333 1 1 1 1: Setting prohibited	R/W
b15 to b12	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

ADPG specifies the gains for the programmable gain amplifiers provided for AN000 to AN002 and AN100 to AN102. The ADPG value should be changed only while the ADCSR.ADST bit is 0.

PGnGAIN[3:0] Bits (Gain Select for ANn Programmable Gain Amplifier) (n = 000 to 002 or 100 to 102)

The PGnGAIN bits specify the gain for the programmable gain amplifier.

28.2.7 Comparator Operating Mode Select Register 0 (ADCMPMD0)

Address: 0008 9012h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	CEN102[1:0]		CEN101[1:0]		CEN100[1:0]		—	—	CEN002[1:0]		CEN001[1:0]		CEN000[1:0]	
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1, b0	CEN000[1:0]	AN000 Comparator Select	b1 b0 0 0:Comparator is not used 0 1:Used as a low-level comparator, which detects a voltage lower than the low reference voltage 1 0:Used as a high-level comparator, which detects a voltage higher than the high reference voltage 1 1:Used as a window comparator, which detects a voltage outside the range from the low reference voltage to the high reference voltage	R/W
b3, b2	CEN001[1:0]	AN001 Comparator Select	b3 b2 0 0:Comparator is not used 0 1:Used as a low-level comparator, which detects a voltage lower than the low reference voltage 1 0:Used as a high-level comparator, which detects a voltage higher than the high reference voltage 1 1:Used as a window comparator, which detects a voltage outside the range from the low reference voltage to the high reference voltage	R/W
b5, b4	CEN002[1:0]	AN002 Comparator Select	b5 b4 0 0:Comparator is not used 0 1:Used as a low-level comparator, which detects a voltage lower than the low reference voltage 1 0:Used as a high-level comparator, which detects a voltage higher than the high reference voltage 1 1:Used as a window comparator, which detects a voltage outside the range from the low reference voltage to the high reference voltage	R/W
b7, b6	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b9, b8	CEN100[1:0]	AN100 Comparator Select	b9 b8 0 0:Comparator is not used 0 1:Used as a low-level comparator, which detects a voltage lower than the low reference voltage 1 0:Used as a high-level comparator, which detects a voltage higher than the high reference voltage 1 1:Used as a window comparator, which detects a voltage outside the range from the low reference voltage to the high reference voltage	R/W
b11, b10	CEN101[1:0]	AN101 Comparator Select	b11 b10 0 0:Comparator is not used 0 1:Used as a low-level comparator, which detects a voltage lower than the low reference voltage 1 0:Used as a high-level comparator, which detects a voltage higher than the high reference voltage 1 1:Used as a window comparator, which detects a voltage outside the range from the low reference voltage to the high reference voltage	R/W
b13, b12	CEN102[1:0]	AN102 Comparator Select	b13 b12 0 0:Comparator is not used 0 1:Used as a low-level comparator, which detects a voltage lower than the low reference voltage 1 0:Used as a high-level comparator, which detects a voltage higher than the high reference voltage 1 1:Used as a window comparator, which detects a voltage outside the range from the low reference voltage to the high reference voltage	R/W
b15, b14	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

ADCMPMD0 specifies whether to use the comparators.

CENn[1:0] Bits (ANn Comparator Select) (n = 000 to 002 or 100 to 102)

The CENn[1:0] bits specify whether to use each comparator and select the operating mode for the comparator.

28.2.8 Comparator Operating Mode Select Register 1 (ADCMPMD1)

Address: 0008 9014h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	VSELL1	VSELH1	CSEL1	—	VSELL0	VSELH0	CSEL0	—	REFH[2:0]			—	REFL[2:0]		
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b2 to b0	REFL[2:0]	Internal Voltage Select for Comparator Low Reference Voltage	b2 b1 b0 0 0 0: Invalid 0 0 1: AVCC0 × 1/8 0 1 0: AVCC0 × 2/8 0 1 1: AVCC0 × 3/8 1 0 0: AVCC0 × 4/8 1 0 1: AVCC0 × 5/8 1 1 0: AVCC0 × 6/8 1 1 1: AVCC0 × 7/8	R/W
b3	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b6 to b4	REFH[2:0]	Internal Voltage Select for Comparator High Reference Voltage	b6 b5 b3 0 0 0: Invalid 0 0 1: AVCC0 × 1/8 0 1 0: AVCC0 × 2/8 0 1 1: AVCC0 × 3/8 1 0 0: AVCC0 × 4/8 1 0 1: AVCC0 × 5/8 1 1 0: AVCC0 × 6/8 1 1 1: AVCC0 × 7/8	R/W
b7	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b8	CSEL0	AN000 to AN002 Comparator Input Select	0:Signal before amplified by the programmable gain amplifier is input to the comparator 1:Signal after amplified by the programmable gain amplifier is input to the comparator	R/W
b9	VSELH0	AN000 to AN002 Comparator High Reference Voltage Select	0: High reference voltage is input from the AN103 pin 1: Internal voltage selected through the REFH[2:0] bits are input as the high reference voltage	R/W
b10	VSELL0	AN000 to AN002 Comparator Low Reference Voltage Select	0: Low reference voltage is input from the AN003 pin 1: Internal voltage selected through the REFL[2:0] bits are input as the low reference voltage	R/W
b11	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b12	CSEL1	AN100 to AN102 Comparator Input Select	0:Signal before amplified by the programmable gain amplifier is input to the comparator 1:Signal after amplified by the programmable gain amplifier is input to the comparator	R/W
b13	VSELH1	AN100 to AN102 Comparator High Reference Voltage Select	0: High reference voltage is input from the AN103 pin 1: Internal voltage selected through the REFH[2:0] bits are input as the high reference voltage	R/W
b14	VSELL1	AN100 to AN102 Comparator Low Reference Voltage Select	0: Low reference voltage is input from the AN003 pin 1: Internal voltage selected through the REFL[2:0] bits are input as the low reference voltage	R/W
b15	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W

ADCMPMD1 specifies comparator input and reference voltages.

REFL[2:0] Bits (Internal Voltage Select for Comparator Low Reference Voltage)

These bits select the value of the voltage when an internal voltage is used as the low reference voltage for the comparator. The range of available voltage settings differs with the conditions of usage, so consult the range of voltage for REFL given in Table 33.16, Comparator Characteristics, and make the setting accordingly.

REFH[2:0] Bits (Internal Voltage Select for Comparator High Reference Voltage)

These bits select the value of the voltage when an internal voltage is used as the low reference voltage for the comparator. The range of available voltage settings differs with the conditions of usage, so consult the range of voltage for REFL given in Table 33.16, Comparator Characteristics, and make the setting accordingly.

CSEL0 Bit (AN000 to AN002 Comparator Input Select)

The CSEL0 bit specifies the input to the comparators for AN000 to AN002.

VSELH0 Bit (AN000 to AN002 Comparator High Reference Voltage Select)

The VSELH0 bit selects the source of the high reference voltage for the AN000 to AN002 comparators.

VSELL0 Bit (AN000 to AN002 Comparator Low Reference Voltage Select)

The VSELL0 bit selects the source of the low reference voltage for the AN000 to AN002 comparators.

CSEL1 Bit (AN100 to AN102 Comparator Input Select)

The CSEL1 bit specifies the input to the comparators for AN100 to AN102.

VSELH1 Bit (AN100 to AN102 Comparator High Reference Voltage Select)

The VSELH1 bit selects the source of the high reference voltage for the AN100 to AN102 comparators

VSELL1 Bit (AN100 to AN102 Comparator Low Reference Voltage Select)

The VSELL1 bit selects the source of the low reference voltage for the AN100 to AN1022 comparators.

28.2.9 Comparator Filter Mode Register 0 (ADCMPNR0)

Address: 0008 9016h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	C002NR[3:0]				C001NR[3:0]				C000NR[3:0]			
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b3 to b0	C000NR[3:0]	AN000 Comparator Noise Cancellation Filter Mode Select	b3 b0 0 0 0 0: Comparator detection results are not sampled 1 0 0 0: Comparator detection results are sampled 16 times with PCLK 1 0 0 1: Comparator detection results are sampled 16 times with PCLK/2 1 0 1 0: Comparator detection results are sampled 16 times with PCLK/4 1 0 1 1: Comparator detection results are sampled 16 times with PCLK/8 1 1 0 0: Comparator detection results are sampled 16 times with PCLK/16 1 1 0 1: Comparator detection results are sampled 16 times with PCLK/128 Others: Setting prohibited	R/W
b7 to b4	C001NR[3:0]	AN001 Comparator Noise Cancellation Filter Mode Select	b7 b4 0 0 0 0: Comparator detection results are not sampled 1 0 0 0: Comparator detection results are sampled 16 times with PCLK 1 0 0 1: Comparator detection results are sampled 16 times with PCLK/2 1 0 1 0: Comparator detection results are sampled 16 times with PCLK/4 1 0 1 1: Comparator detection results are sampled 16 times with PCLK/8 1 1 0 0: Comparator detection results are sampled 16 times with PCLK/16 1 1 0 1: Comparator detection results are sampled 16 times with PCLK/128 Others: Setting prohibited	R/W
b11 to b8	C002NR[3:0]	AN002 Comparator Noise Cancellation Filter Mode Select	b11 b8 0 0 0 0: Comparator detection results are not sampled 1 0 0 0: Comparator detection results are sampled 16 times with PCLK 1 0 0 1: Comparator detection results are sampled 16 times with PCLK/2 1 0 1 0: Comparator detection results are sampled 16 times with PCLK/4 1 0 1 1: Comparator detection results are sampled 16 times with PCLK/8 1 1 0 0: Comparator detection results are sampled 16 times with PCLK/16 1 1 0 1: Comparator detection results are sampled 16 times with PCLK/128 Others: Setting prohibited	R/W
b15 to b12	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

ADCMPNR0 specifies the noise filter operation for the AN000 to AN002 comparators.

CnNR[3:0] Bits (ANn Comparator Noise Cancellation Filter Mode Select) (n = 000 to 002)

The CnNR[3:0] bits specify the noise filter operation for the ANn comparator. The comparator detection results are sampled as specified in these bits, and when the specified voltage condition is detected at all sampled points, the ADCMPFR.CnFLAG is set. At this time, a comparator interrupt (CMPI) request and a port output enable 3 (POE3) startup request can be issued according to the ADCMPSEL setting.

28.2.10 Comparator Filter Mode Register 1 (ADCMPNR1)

Address: 0008 9016h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	C102NR[3:0]				C101NR[3:0]				C100NR[3:0]			
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b3 to b0	C100NR[3:0]	AN100 Comparator Noise Cancellation Filter Mode Select	b3 b0 0 0 0 0: Comparator detection results are not sampled 1 0 0 0: Comparator detection results are sampled 16 times with PCLK 1 0 0 1: Comparator detection results are sampled 16 times with PCLK/2 1 0 1 0: Comparator detection results are sampled 16 times with PCLK/4 1 0 1 1: Comparator detection results are sampled 16 times with PCLK/8 1 1 0 0: Comparator detection results are sampled 16 times with PCLK/16 1 1 0 1: Comparator detection results are sampled 16 times with PCLK/128 Others: Setting prohibited	R/W
b7 to b4	C101NR[3:0]	AN101 Comparator Noise Cancellation Filter Mode Select	b7 b4 0 0 0 0: Comparator detection results are not sampled 1 0 0 0: Comparator detection results are sampled 16 times with PCLK 1 0 0 1: Comparator detection results are sampled 16 times with PCLK/2 1 0 1 0: Comparator detection results are sampled 16 times with PCLK/4 1 0 1 1: Comparator detection results are sampled 16 times with PCLK/8 1 1 0 0: Comparator detection results are sampled 16 times with PCLK/16 1 1 0 1: Comparator detection results are sampled 16 times with PCLK/128 Others: Setting prohibited	R/W
b11 to b8	C102NR[3:0]	AN102 Comparator Noise Cancellation Filter Mode Select	b11 b8 0 0 0 0: Comparator detection results are not sampled 1 0 0 0: Comparator detection results are sampled 16 times with PCLK 1 0 0 1: Comparator detection results are sampled 16 times with PCLK/2 1 0 1 0: Comparator detection results are sampled 16 times with PCLK/4 1 0 1 1: Comparator detection results are sampled 16 times with PCLK/8 1 1 0 0: Comparator detection results are sampled 16 times with PCLK/16 1 1 0 1: Comparator detection results are sampled 16 times with PCLK/128 Others: Setting prohibited	R/W
b15 to b12	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

ADCMPNR1 specifies the noise filter operation for the AN100 to AN102 comparators.

CnNR[3:0] Bits (ANn Comparator Noise Cancellation Filter Mode Select) (n = 100 to 102)

The CnNR[3:0] bits specify the noise filter operation for the ANn comparator. The comparator detection results are sampled as specified in these bits, and when the specified voltage condition is detected at all sampled points, the ADCMPFR.CnFLAG is set. At this time, a comparator interrupt (CMPI) request and a port output enable 3 (POE3) startup request can be issued according to the ADCMPSEL setting.

28.2.11 Comparator Detection Flag Register (ADCMPFR)

Address: 0008 901Ah

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	C102FLAG	C101FLAG	C100FLAG	C002FLAG	C001FLAG	C000FLAG
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	C000FLAG	AN000 Comparator Detection Flag	0: Specified condition is detected in the comparator 1: Specified condition is not detected in the comparator	R/(W)*
b1	C001FLAG	AN001 Comparator Detection Flag	0: Specified condition is detected in the comparator 1: Specified condition is not detected in the comparator	R/(W)*
b2	C002FLAG	AN002 Comparator Detection Flag	0: Specified condition is detected in the comparator 1: Specified condition is not detected in the comparator	R/(W)*
b3	C100FLAG	AN100 Comparator Detection Flag	0: Specified condition is detected in the comparator 1: Specified condition is not detected in the comparator	R/(W)*
b4	C101FLAG	AN101 Comparator Detection Flag	0: Specified condition is detected in the comparator 1: Specified condition is not detected in the comparator	R/(W)*
b5	C102FLAG	AN102 Comparator Detection Flag	0: Specified condition is detected in the comparator 1: Specified condition is not detected in the comparator	R/(W)*
b7, b6	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

Note 1. Only 0 can be written to clear the flag.

ADCMPFR is a flag register that indicates whether each comparator has detected the specified voltage condition.

CnFLAG Bit (ANn Comparator Detection Flag) (n = 000 to 002 or 100 to 102)

The CnFLAG flag indicates whether each comparator has detected the specified voltage condition.

[Setting Condition]

- When the comparator detection results are sampled 16 times with the clock selected by the ADCMPNRn.CmNR[3:0] (n = 0 or 1, m = 000 to 002 or 100 to 102) bits and the specified condition is detected at all sampled points

[Clearing Condition]

- When 0 is written to the bit by software

28.2.12 Comparator Interrupt Select Register (ADCMPSEL)

Address: 0008 901Ch

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	POERQ	IE	—	—	SEL102	SEL101	SEL100	SEL002	SEL001	SEL000
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	SEL000	AN000 Comparator Detection Select	0: Detection in the comparator is not used as an interrupt or a POE request 1: Detection in the comparator is used as an interrupt or a POE request	R/W
b1	SEL001	AN001 Comparator Detection Select	0: Detection in the comparator is not used as an interrupt or a POE request 1: Detection in the comparator is used as an interrupt or a POE request	R/W
b2	SEL002	AN002 Comparator Detection Select	0: Detection in the comparator is not used as an interrupt or a POE request 1: Detection in the comparator is used as an interrupt or a POE request	R/W
b3	SEL100	AN100 Comparator Detection Select	0: Detection in the comparator is not used as an interrupt or a POE request 1: Detection in the comparator is used as an interrupt or a POE request	R/W
b4	SEL101	AN101 Comparator Detection Select	0: Detection in the comparator is not used as an interrupt or a POE request 1: Detection in the comparator is used as an interrupt or a POE request	R/W
b5	SEL102	AN102 Comparator Detection Select	0: Detection in the comparator is not used as an interrupt or a POE request 1: Detection in the comparator is used as an interrupt or a POE request	R/W
b7, b6	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b8	IE	Interrupt Enable	0: CMPI interrupt by specified condition detection in the comparator is disabled 1: CMPI interrupt by specified condition detection in the comparator is enabled	R/W
b9	POERQ	POE Request Set	0: POE request by specified condition detection in the comparator is disabled 1: POE request by specified condition detection in the comparator is enabled	R/W
b15 to b10	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

ADCMPSEL specifies whether to use specified condition detection in the comparator as an interrupt or POE request.

SELn Bit (ANn Comparator Detection Select) (n = 000 to 002 or 100 to 102)

The SELn bit specifies whether to use specified condition detection in each comparator as an interrupt or POE request.

IE Bit (Interrupt Enable)

The IE bit enables or disables comparator detection interrupt (CMPI) generation. A CMPI interrupt is generated by ORing the comparator detection states selected by the SELn bits.

POE Bit (POE Request Set)

The POE bit enables or disables POE request generation by specified condition detection in the comparator. A POE request is generated by ORing the comparator detection states selected by the SELn bits.

28.2.13 A/D Sampling State Register (ADSSTR)

Address: S12AD0.ADSSTR 0008 9060h, S12AD1.ADSSTR 0008 90E0h

	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	0	0	0	1	0	1	0	0

ADSSTR is an 8-bit readable/writable register that is used to set the sampling time for analog inputs.
Sampling time is adjustable when the signal source impedance of analog input is high and the sampling time is insufficient or the speed of A/D conversion clock (ADCLK) is low.
Set the value of 0Dh or larger.
Ensure to rewrite this register while the A/D conversion is stopped (the ADST bit in ADCSR = 0) in order to prevent incorrect operation.
For details, see section 28.3.3, Analog Input Sampling and A/D Conversion Time.

28.3 Operation

28.3.1 Single Mode

In single mode, A/D conversion is to be performed for only once on the analog input of the specified single channel as below.

(1) A/D conversion for the selected channel is started when the ADST bit in ADCSR is set to 1 (A/D conversion start) by software, MTU3, GPT, or an external trigger input.

(2) When A/D conversion is completed, the A/D conversion result is stored in the A/D data register n (ADDRn) corresponding to the channel.0A,

(3) When A/D conversion is completed, if the ADCSR.ADIE bit is set to 1 (S12ADI interrupt enable by completing A/D conversion), an S12ADI interrupt request is generated.

(4) The ADCSR.ADST bit remains at 1 (A/D conversion start) during A/D conversion, and is automatically cleared to 0 when A/D conversion ends. Then the A/D converter enters a wait state.

(5) If the ADCSR.ADST bit is cleared to 0 during A/D conversion (A/D conversion stop), A/D conversion stops and the A/D converter enters a wait state.

Figure 28.2 shows an example of operation when AN001 is selected as an analog input.

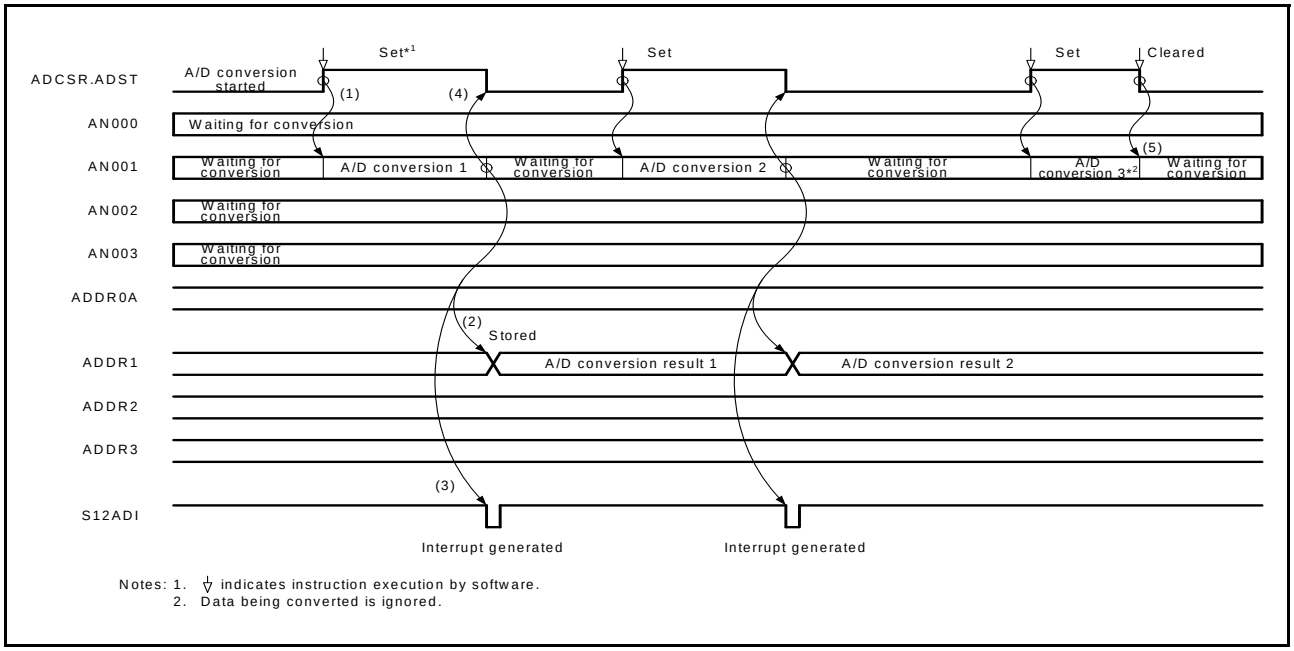


Figure 28.2 Example of A/D Converter Operation (Single Mode)

28.3.2 Scan Conversion

A scan conversion is performed in three operating modes: single-cycle scan mode, continuous scan mode, and 2-channel scan mode.

In single-cycle scan mode, one or more specified channels are scanned once and conversion stops. In continuous scan mode, one or more specified channels are scanned repeatedly until the ADCSR.ADST bit is modified from 1 to 0 by software. In 2-channel scan mode, four analog input channels are separated into groups 0 and 1, and a separate startup trigger can be specified for each group. Conversion in each group is the same as that in single-cycle scan mode (one or more channels are scanned once and conversion stops).

28.3.2.1 Single-Cycle Scan Mode

In single-cycle scan mode, A/D conversion is to be performed only once on the analog input of the specified single channel as below.

(1) When the ADCSR.ADST bit is set to 1 (A/D conversion start) by software, MTU3, GPT, or an external trigger input, A/D conversion is performed for ANn channels in the order selected by the CH[1:0] bits in ADANS.

(2) When A/D conversion for a channel is completed, the A/D conversion result is stored in the A/D data register n (ADDRn) corresponding to the channel.(n = 0A, 0B, 1 to 3)

(3) When A/D conversion of all selected channels is completed, if the ADCSR.ADIE bit is set to 1 (S12ADI interrupt enable by completing A/D conversion), an S12ADI interrupt request is generated.

(4) The ADST bit remains at 1 (A/D conversion start) during A/D conversion, and is automatically cleared to 0 when A/D conversion of all selected channels ends. Then the A/D converter enters a wait state.

Note that sampling operation depends on the ADCER.SHBYP bit setting. Figure 28.3 shows an example of operation when ADCER.SHBYP = 0, and Figure 28.4 shows an example when ADCER.SHBYP = 1.

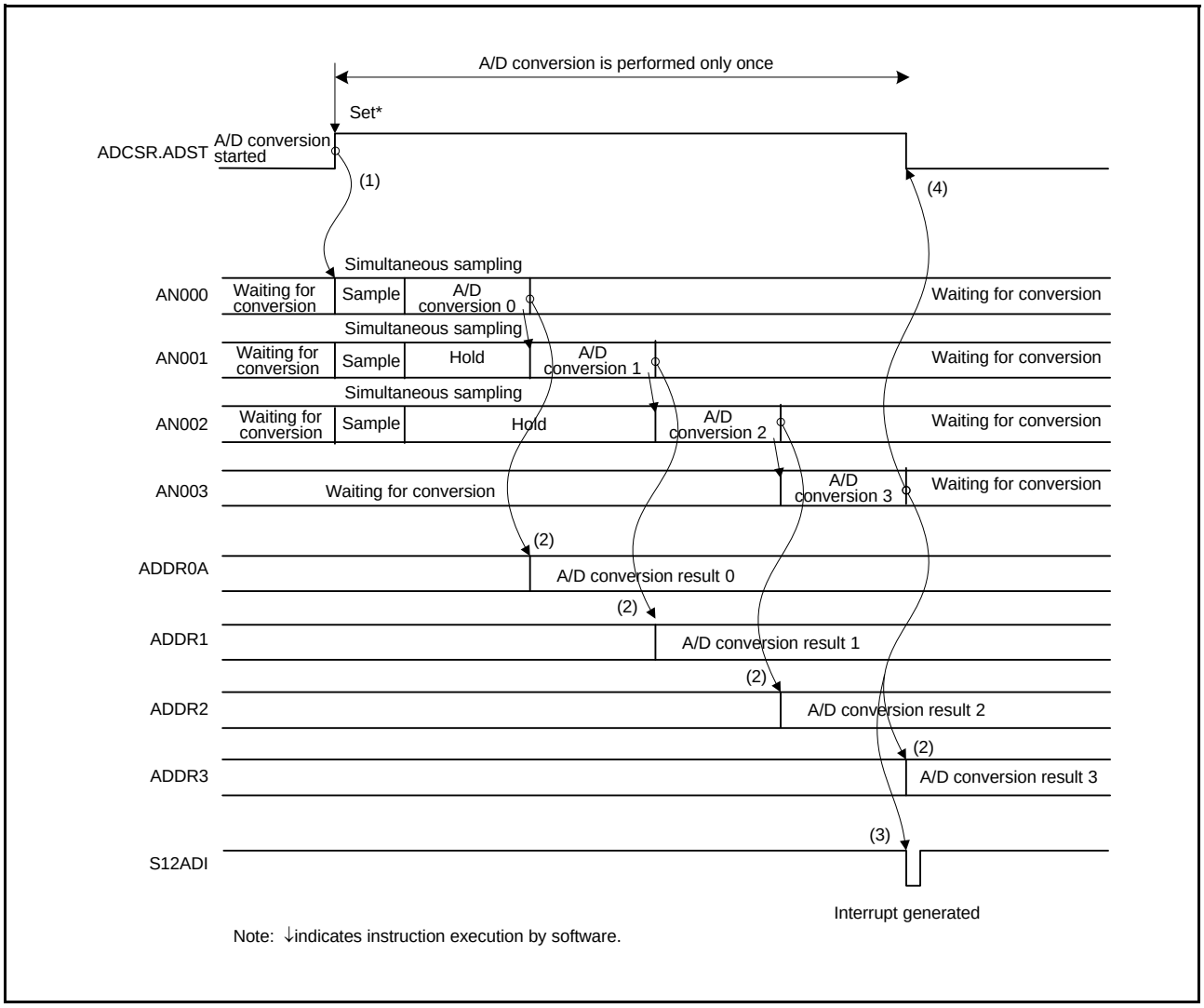


Figure 28.3 Example of Operation in Single-Cycle Scan Mode (ADCER.SHBYP = 0: Sample-and-Hold Circuit Dedicated for Channel is Used)

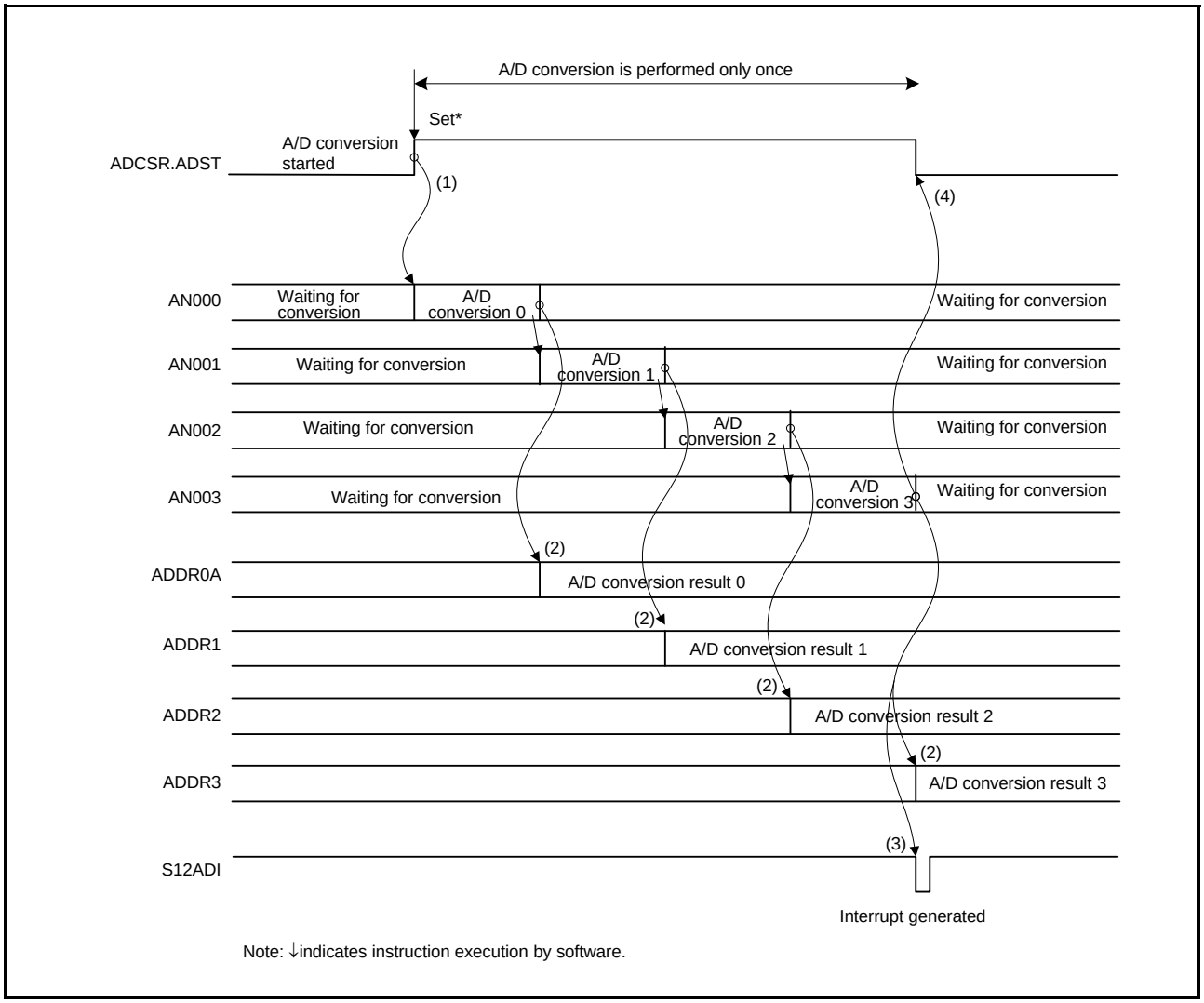


Figure 28.4 Example of Operation in Single-Cycle Scan Mode (ADCER.SHBYP = 1: Sample-and-Hold Circuit Dedicated for Channel is Not Used)

28.3.2.2 Continuous Scan Mode

In continuous scan mode, A/D conversion is to be performed repeatedly on the analog inputs of the specified channels as below.

(1) When the ADCSR.ADST bit is set to 1 (A/D conversion start) by software, MTU3, GPT, or an external trigger input, A/D conversion is performed for ANn channels in the order selected by the CH[1:0] bits in ADANS.

(2) When A/D conversion for a channel is completed, the A/D conversion result is stored in the corresponding A/D data register n (ADDRn).(n = 0A, 0B, 1 to 3)

(3) When A/D conversion of all selected channels is completed, if the ADCSR.ADIE bit is set to 1 (S12ADI interrupt enable by completing A/D conversion), an S12ADI interrupt request is generated. A/D converter starts A/D conversion for ANn channels in the order selected by the CH[1:0] bits in ADANS.

(4) The ADST bit is not cleared automatically, and steps (2) and (3) are repeated as long as the ADST bit remains set to 1 (A/D conversion start). When the ADST bit is cleared to 0 (A/D conversion stop), A/D conversion stops and the A/D converter enters a wait state.

(5) If the ADST bit is later set to 1 (A/D conversion start), A/D conversion starts again for ANn channels in the order selected by the CH[1:0] bits in ADANS.

Note that sampling operation depends on the ADCER.SHBYP bit setting. Figure 28.5 shows an example of operation when ADCER.SHBYP = 0, and Figure 28.6 shows an example when ADCER.SHBYP = 1.

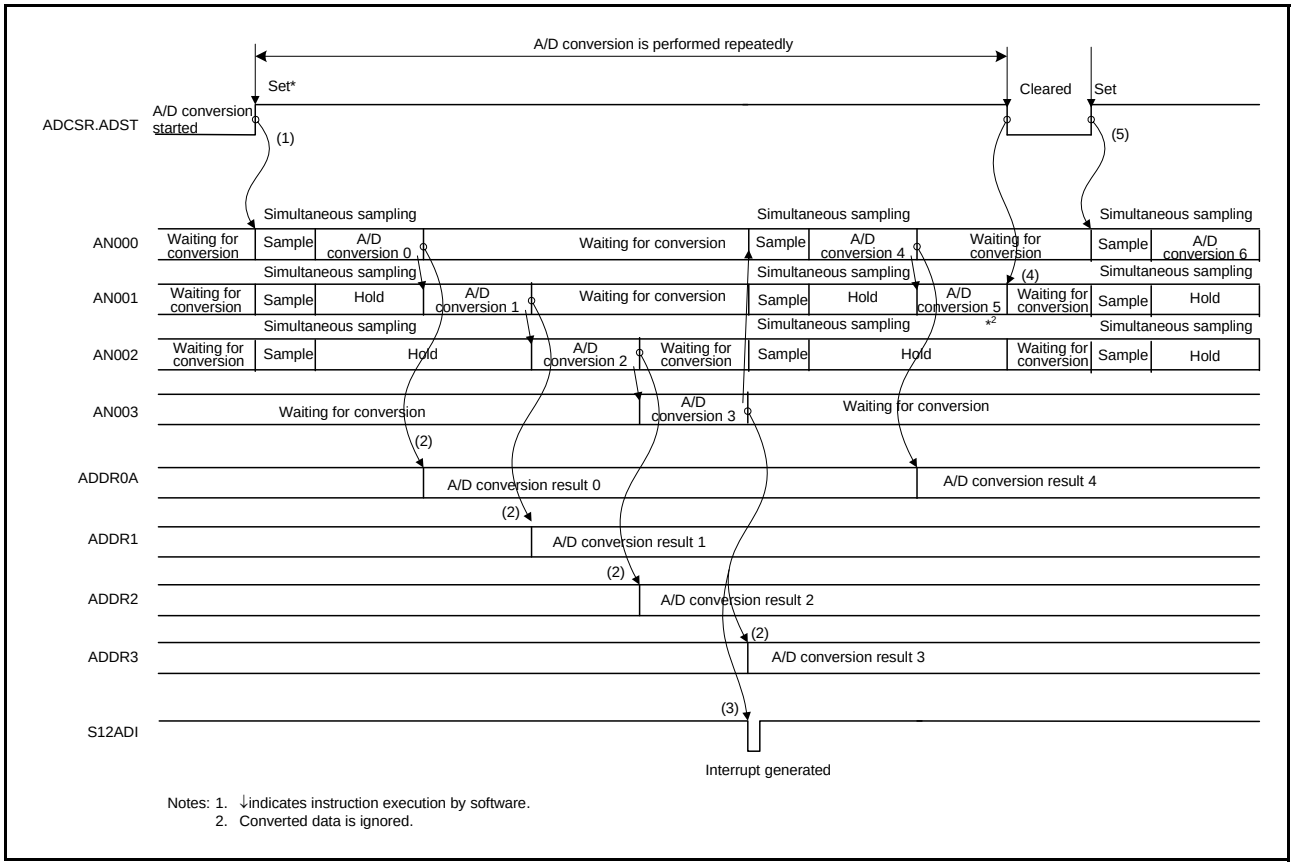


Figure 28.5 Example of Operation in Continuous Scan Mode (ADCER.SHBYP = 0: Sample-and-Hold Circuit Dedicated for Channel is Used)

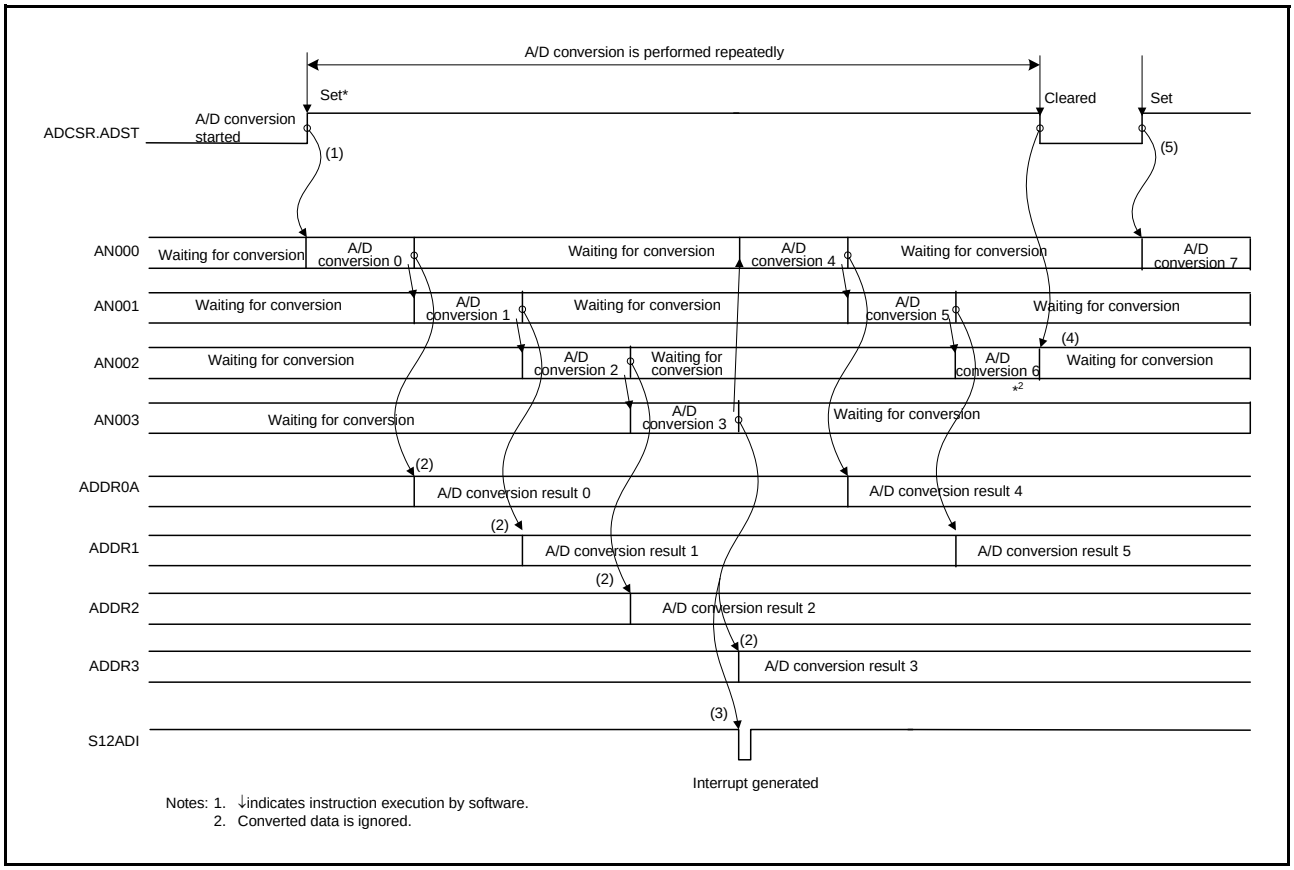


Figure 28.6 Example of Operation in Continuous Scan Mode (ADCER.SHBYP = 1: Sample-and-Hold Circuit Dedicated for Channel is Not Used)

28.3.2.3 2-Channel Scan Mode

In 2-channel scan mode, four analog input channels are separated into groups 0 and 1, and a separate startup trigger can be selected for each group. The timing for generating a conversion end interrupt in 2-channel scan mode can be set to the end of group 0 or 1 or the end of both groups.

When using a trigger to start conversion, select different trigger sources for groups 0 and 1 through the ADSTRGR settings. Note that if a startup request for group 1 is generated during conversion of group 0, the startup request for group 1 is ignored.

Figure 28.7 shows an example of operation when TRG4AN in MTU4 is selected for the A/D conversion startup request for group 0, TRG4BN in MTU4 is selected for group 1, and the ADANS.CH[1:0] bits are set to 01b.

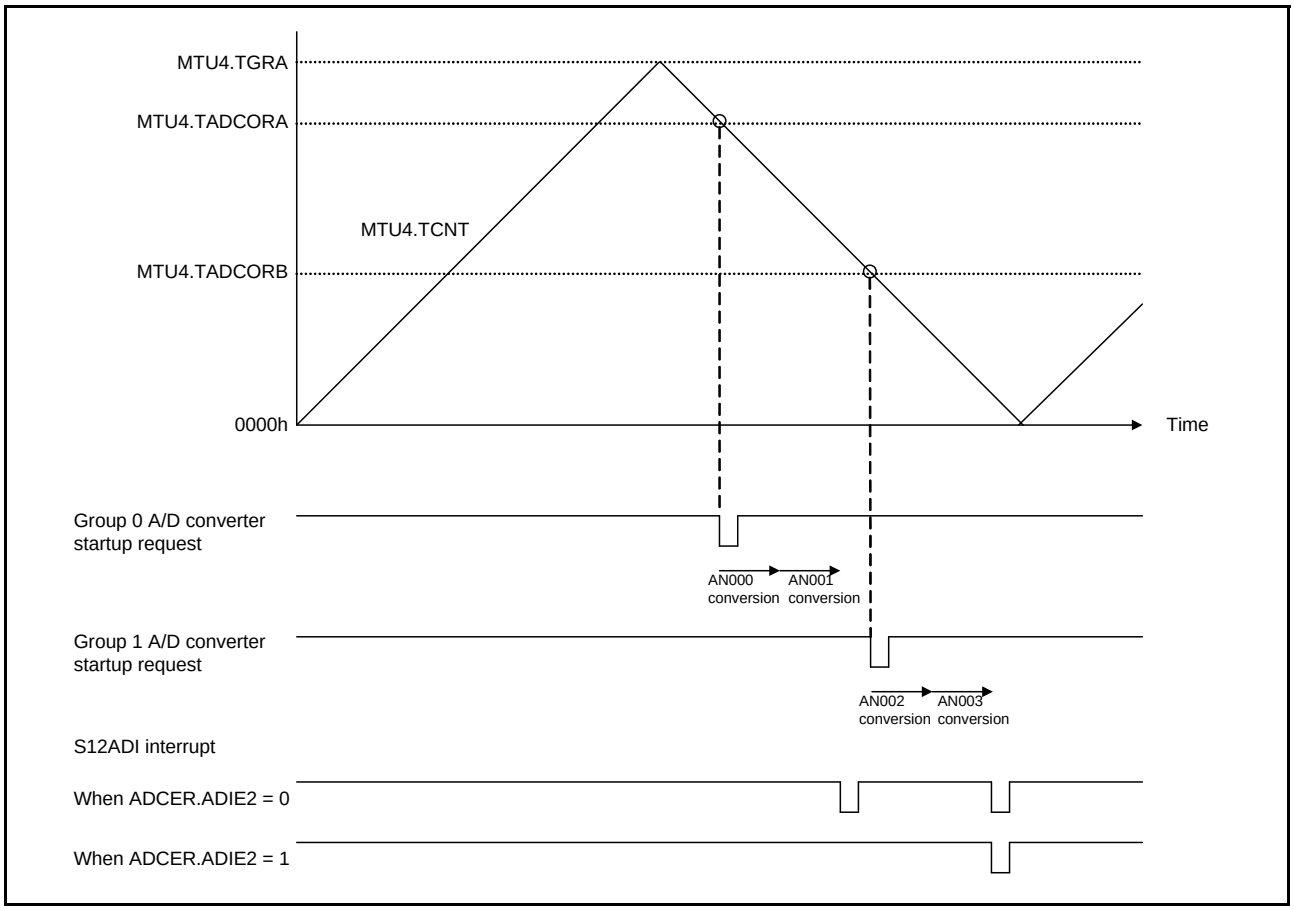


Figure 28.7 Example of Operation in 2-Channel Scan Mode

28.3.3 Analog Input Sampling and A/D Conversion Time

A/D converter activation can be selected from software activation, activation by triggers from MTU3 and GPT, and activation by ADTRGn# (external trigger). After the start-of-A/D-conversion delay time (tD) has passed, the A/D converter samples the analog input, performs self diagnostic, and then begins the A/D conversion process.
The A/D conversion time (tSCAN) includes the start-of-A/D-conversion delay time (tD), dedicated sample-and-hold circuit sampling time (tSPLSH), self diagnostic time (tDIAG), A/D conversion processing time (tCONV), and end-of-A/D-conversion delay time (tED).
The A/D conversion processing time (tCONV) is the sum of the input sampling time (tSPL) and successive conversion time (tSAM).
The input sampling time (tSPL) is the time for charging the input capacitance of the A/D converter's sample-and-hold circuit. If the impedance of the analog input signal source is high and the sampling time is insufficient or the A/D conversion clock (ADCLK) is running at low speed, the sampling time can be adjusted by using the ADSSTR.
The successive conversion time (tSAM) is fixed at 30 states of ADCLK.
Table 28.8 shows ADSSTR setting examples and Table 28.8 shows the A/D conversion time.
The A/D conversion time (tSCAN) in single-cycle scan mode for which the number of selected channels is n can be determined as follows.

(1) For AN000 to AN002 and AN100 to AN102

- Neither dedicated sample-and-hold circuit nor self diagnostic function is used
  tSCAN = tD + (tCONV × n) + tED
- Dedicated sample-and-hold circuit is not used and self diagnostic function is used
  tSCAN = tD + tDIAG + (tCONV × n) + tED
- Dedicated sample-and-hold circuit is used and self diagnostic function is not used
  tSCAN = tD + tSPLSH + (tCONV × n) + tED
- Both dedicated sample-and-hold circuit and self diagnostic function are used
  tSCAN = tD + tSPLSH + tDIAG + (tCONV × n) + tED

(2) For AN003 and AN103

- Self diagnostic function is not used
  tSCAN = tD + (tCONV × n) + tED
- Self diagnostic function is used
  tSCAN = tD + tDIAG + (tCONV × n) + tED

The conversion time for the first cycle in single mode or continuous scan mode is the same as that for single-cycle scan mode.
The conversion time for the second and subsequent cycles in continuous scan mode is tSCAN in single-cycle scan mode minus tD.

Table 28.8 Examples of ADSSTR Setting

Example of Setting	Setting Range	Sampling Time*
Standard (initial value)	14h	0.4 µs (When PCLK = ADCLK = 50 MHz)
Analog input signal impedance is high and the sampling time may be insufficient	15h to FFh	Example: FFh 5.1 µs (When PCLK = ADCLK = 50 MHz)
Input sampling time should be less than the initial value when ADCLK is below 50 MHz	0Dh to 13h	Example: 10h 0.4 µs (When PCLK = ADCLK = 40 MHz)

Note 1. Note: * Set the sampling time ≥ 0.4 µs. Sampling time is obtained by the following equation.

$$\text{Sampling time } (\mu s) = \frac{\text{ADSSTR register setting}}{\text{ADCLK (MHz)}}$$

Table 28.9 A/D Conversion Time

Item		Symbol		ADTRGn# (External Trigger)	MTU3 and GPT Trigger	Software Activation	Unit
Start-of-A/D-conversion delay time*2		tD		4PCLK + 3ADCLK*1	3PCLK + 3ADCLK	2PCLK + 3ADCLK	Cycle
Processing time required for the independent sample-and-hold circuit dedicated for channel	Sampling time	tSPLSH	tSH	20ADCLK			
	Sampling-to-A/D conversion wait time		tW	10ADCLK			
Self diagnostic conversion processing time	Sampling time	tDIAG	tSPL	ADSSTR setting (initial value is 20) × ADCLK			
	Successive conversion time		tSAM	30ADCLK			
A/D conversion processing time	Sampling time	tCONV	tSPL	ADSSTR setting (initial value is 20) × ADCLK			
	Successive conversion time		tSAM	30ADCLK			
End-of-A/D-conversion delay time*3		tED		1PCLK + 5ADCLK			

PCLK: Module clock, ADCLK: A/D conversion clock

Note 1. For the timing of external trigger input, see section 33.3.3, Timing of On-Chip Peripheral Modules.
Note 2. This is the maximum time from software writing or trigger input to the start of A/D conversion.
Note 3. This is the time from the end of A/D conversion to generation of an A/D conversion end interrupt.

28.3.4 Usage Example of ADDRn Register Automatic Clearing Function (n = 0A, 0B, 1 to 3)

Setting the ADCER.ACE bit to 1 automatically clears the A/D data registers n (ADDRn and ADRD) to 0000h when the ADDRn and ADRD registers are read by the CPU or DTC.

This function is used to detect update failures of the ADDRn and ADRD registers.

Examples in which the function to automatically clear the ADDRn registers are enabled and disabled are shown below.

In a case where the ACE bit in ADCER is 0 (automatic clearing is disabled), if the A/D conversion result (0222h) is not written to the ADDRn registers for some reason, the old data (0111h) will become the ADDRn value. Furthermore, if this ADDRn value is written to a general register using an A/D conversion end interrupt, the old data (0111h) will be saved in the general register. When checking data that has not been updated, it is necessary to frequently save the old data in the RAM or a general register.

In a case where the ACE bit in ADCER is 1 (automatic clearing is enabled), when ADDRn = 0111h is read by the CPU or DTC, ADDRn is automatically cleared to 0000h. After that, if the A/D conversion result of 0222h cannot be transferred to ADDRn for some reason, the cleared data (0000h) remains as the ADDRn value. If this ADDRn value is written to a general register using an A/D scan conversion end interrupt at this point, 0000h will be saved in the general register. Occurrence of an ADDRn update failure can be determined by simply checking whether the read data value is 0000h.

If automatic clearing of the ADDRn registers is selected, when data is read from the ADDRn registers, the converted data will be cleared.

28.3.5 Operation of Double Data Registers (Only for ADDR0)

When analog input AN000 or AN100 is selected and the startup source is set through the ADSTRGR.ADSTRSn[4:0] bits to "TRGnAN or TRGnBN in MTU3 (n = 4 or 7)" (ADSTRGR.ADSTRSn[4:0] bits = 01011b or 01111b) or "GTADTRAnN or GTADTRBnN in GPT (n = 0 to 3)" (ADSTRGR.ADSTRSn[4:0] bits = 11001b to 11100b), the AN000 or AN100 conversion results are stored in separate registers according to the startup trigger. When conversion is started by TRGnAN in MTU3 or GTADTRAnN in GPT, the AN000 or AN100 conversion result is stored in ADDR0A. When conversion is started by TRGnBN in MTU3 or GTADTRBnN in GPT, the AN000 or AN100 conversion result is stored in ADDR0B. The timing for generating a conversion end interrupt can be set to the end of conversion started by the later one of the two triggers or the end of conversion started by each trigger through the ADCER.ADIEW setting. Figure 28.8 shows an example of operation when AN000 is selected, TRG4AN or TRG4BN in MTU3 is selected as the trigger, and conversion is started in single mode.

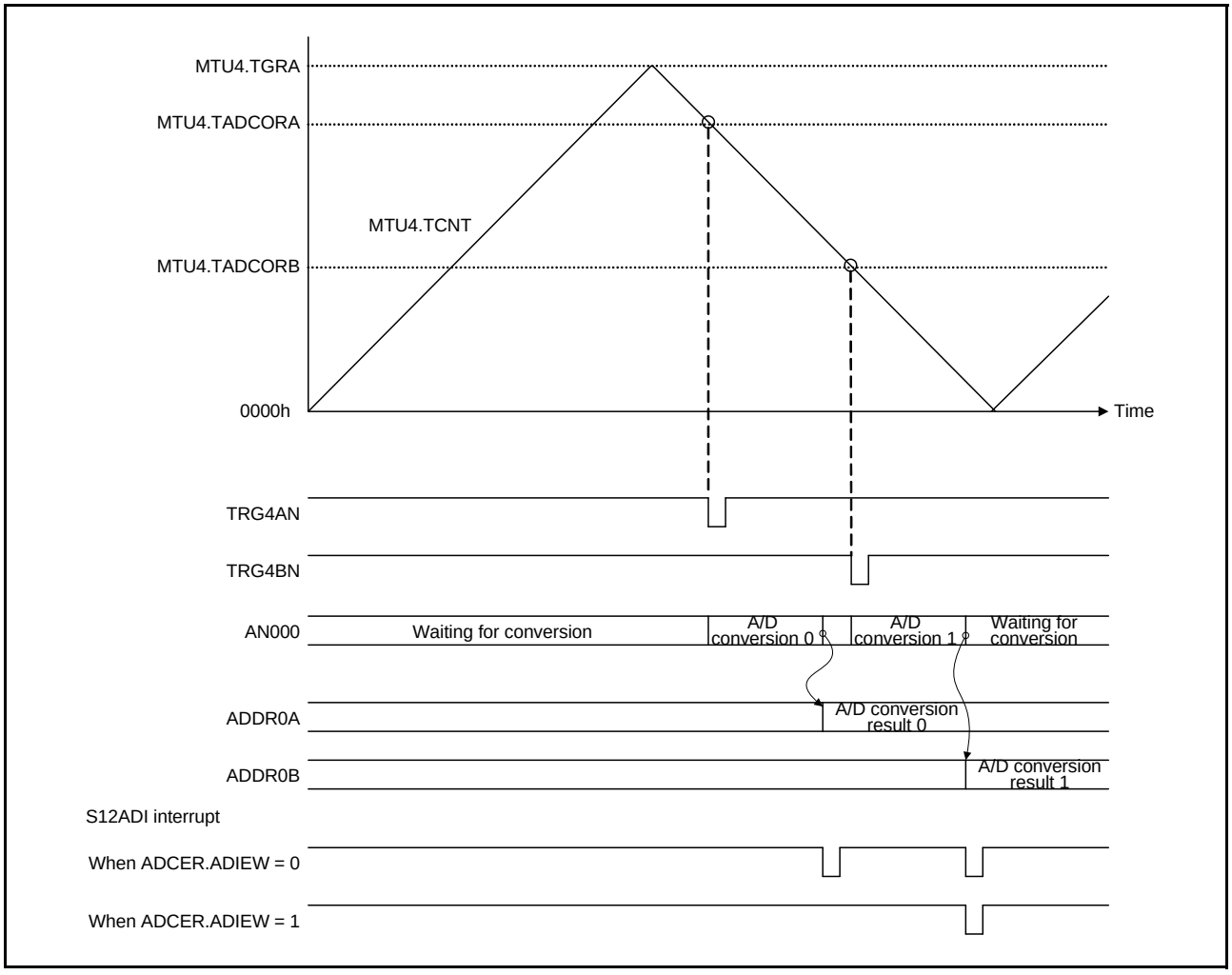


Figure 28.8 Example of Double Data Register Operation

28.3.6 Programmable Gain Amplifier

A programmable gain amplifier is provided for each of the AN000 to AN002 and AN100 to AN102 pins.
The gain can be selected through the ADPG.PGnGAIN[3:0] bits (n = 000 to 002 or 100 to 102), and the operational amplifier to be used can be selected through the ADANS.PGnEN and ADANS.PGnSEL bits.
The ADCER.SHBYP bit must be 0 (the sample and hold circuit is in use) if the programmable gain amplifier is to be used.

28.3.7 Comparator

A comparator is provided for each of the AN000 to AN002 and AN100 to AN102 pins. The comparator operation can be selected from three modes: low-level comparator operation which detects that the analog input voltage is lower than the low reference voltage, high-level comparator operation which detects that the analog input voltage is higher than the high reference voltage, and window comparator operation which detects that the analog input voltage is outside the range from the low reference voltage to the high reference voltage. The analog input before or after programmable gain amplification can be selected as the voltage for comparison. The reference voltages can be selected from the input from the pins (low reference: AN003/CVREFL; high reference: AN103/CVREFH) and internally-generated voltage (1/8 × AVCC0 to 7/8 × AVCC0). A noise cancellation circuit is provided for the comparator detection results; detection results are sampled 16 times with 1/PCLK to 128/PCLK and only when the specified voltage level is detected at all sampled points, the detection flag is set and an interrupt (CMPI) or a POE request (request for placing the complementary PWM output pins in the MTU3 and GPT output pins in high-impedance state) can be generated.
The following shows an example of comparator settings.

1. Select the voltage before or after programmable gain amplification as the voltage for comparison through the ADCMPMD1.CSELn bits (n = 0 or 1).
2. Select the pin inputs or internally-generated voltages as the reference voltages through the ADCMPMD1.VSELLn bits (n = 0 or 1) and ADCMPMD1.VSELHn bits (n = 0 or 1). When the internally-generated voltages are selected, specify the high reference voltage through the ADCMPMD1.REFL[2:0] bits and the low reference voltage through the ADCMPMD1.REFH[2:0] bits.
3. Set up the noise cancellation circuit for each comparator through the ADCMPNRn.CmNR[3:0] bits (n = 0 or 1, m = 000 to 002 or 100 to 102).
4. Select whether to generate an interrupt request (CMPI) or a POE request on detection of the specified condition in each comparator through the ADCMPSEL.SELm bits (m = 000 to 002 or 100 to 102). To generate an interrupt request (CMPI) or a POE request, enable interrupt requests (CMPI) through the ADCMPSEL.IE bit or enable POE requests through the ADCMPSEL.POE bit.
5. Select the comparator to be used and the comparator operating mode through the ADCMPMD0.CENm[1:0] bits.

Figure 28.9 shows an example of comparator operation.

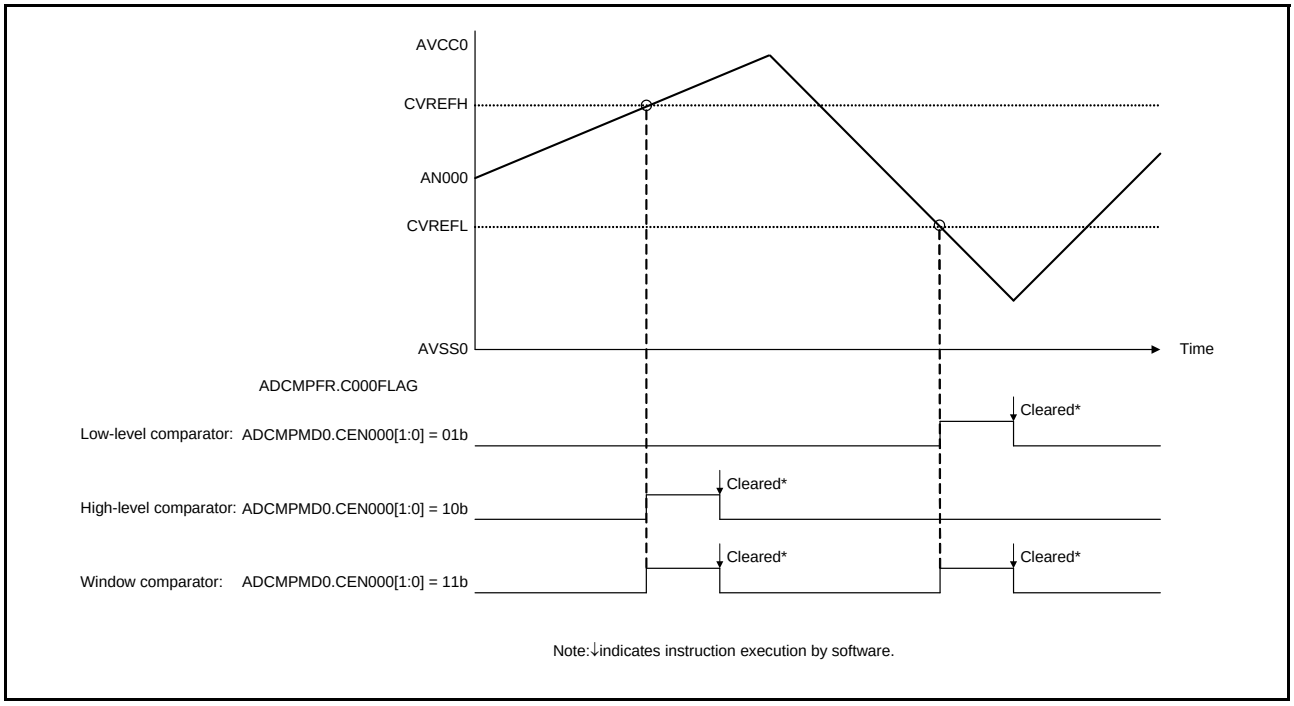


Figure 28.9 Example of Comparator Operation (Reference Voltages are Input from Pins)

28.3.8 Starting A/D Conversion with External Trigger

The A/D converter can be activated by the input of an external trigger. To start up the A/D converter by an external trigger, the pin function should be set up using PFAADC. After setting the A/D start trigger select register (ADSTRGR) to 00h and applying a high-level signal to the ADTRGn# pin, both the ADCSR.TRGE and ADCSR.EXTRG bits should be set to 1. Figure 28.10 shows a timing diagram of the external trigger input.
For details on pin function settings, see section 15, I/O Ports.

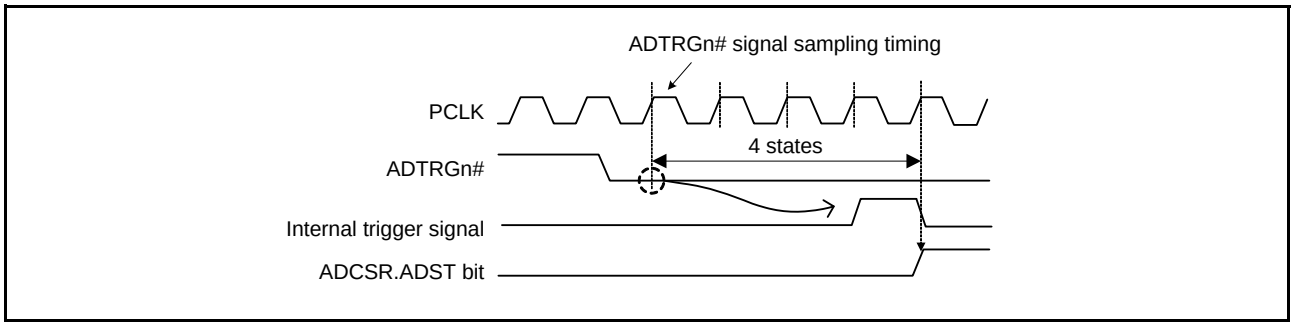


Figure 28.10 External Trigger Input Timing

28.3.9 Starting A/D Conversion with Trigger from Peripheral Modules

A/D conversion can be activated by a timer trigger of the MTU3 or GPT. To start up A/D conversion by a timer trigger, the ADCSR.TRGE bit should be set to 1, the ADCSR.EXTRG bit should be cleared to 0, and the relevant source should be selected by ADSTRGR.ADSTRS[4:0] bits.

28.4 Interrupt Sources and DTC Transfer Request

28.4.1 Interrupt Request on Completion of Each A/D Conversion

The A/D converter can send an A/D conversion end interrupt request (S12ADI) to the CPU.
By setting the ADCSR.ADIE bit to 1, an S12ADI interrupt is enabled; by clearing the ADIE bit to 0, an S12ADI interrupt is disabled.
In addition, the DTC can be started up when an S12ADI interrupt is generated. Using an S12ADI interrupt to allow the DTC to read the converted data enables continuous conversion without burden on software.
For details on DTC settings, see section 14, Data Transfer Controller (DTC).

28.4.2 Interrupt Request on Detection of Comparator

The comparator can send a converter detection interrupt request (CMPI) to the CPU.
After setting any of bits SEL000 to 002, or 100 to 102 in ADCMPSEL to 1, setting the ADCMPSEL.IE bit to 1 or 0 enables or disables the CMPI interrupt, respectively. However, while a comparator detection flag in the comparator detection flag register (ADCMPFR) is 1, an interrupt request is ignored. Therefore, set the corresponding flag to 0 to enable the interrupt.

28.5 Usage Notes

28.5.1 Module Stop Function Setting

Operation of the A/D converter can be disabled or enabled using the module stop control register. The initial setting is for operation of the A/D converter to be halted. A/D converter registers can be accessed after the module stop state is canceled. For details, see section 9, Low Power Consumption.

28.5.2 Notes on Restarting A/D Conversion

Stopping analog input to the A/D converter by clearing the ADCSR.ADST bit to 0 requires two cycles of the ADCLK. Starting analog input to the A/D converter by setting the ADCSR.ADST bit to 1 requires three cycles of the ADCLK. Before restarting A/D conversion, be sure to perform self diagnostic.

28.5.3 Point for Caution Regarding Countermeasures for Noise

To disable A/D conversion when an external trigger or timer has been selected as the condition for starting A/D conversion, set the ADCSR.TRGE bit to 0 to select the software trigger as the trigger to start A/D conversion, and then set the ADCSR.ADST bit to 0 (to stop A/D conversion).

28.5.4 Notes on Entering Low Power Consumption States

When the RX62T Group enters the module stop state or software standby mode, make sure to stop the A/D conversion. To do so, set the ADST bit in ADCSR to 0, and allow time for disabling of the analog input to the A/D converter. Follow the procedure given below to ensure that this time is secured.

(1) Set the ADCSR.TRGE bit to 0 (software trigger).
(2) Clear the ADCSR.ADST bit to 0.
(3) Set the ADCR.CKS[1:0] bits to 11b (PCLK).
(4) After confirming that the A/D converter has been disabled (at least 6 PCLK cycles are required to stop the conversion), place the LSI in the module stop state or software standby mode.

After the module stop state, software standby mode, or deep software standby mode is entered, part of the A/D converter is in operation waiting state. To place the A/D converter in standby state completely, set the MSTPCRA.MSTPA24 bit to 1. In this case, after the module stop state, software standby mode, or deep software standby mode is canceled, clear the STPCRA.MSTPA24 bit to 0 and then wait for 10 ms before starting A/D conversion.

28.5.5 Permissible Impedance of Signal Sources

To realize high-speed conversion 1.0 µs, the A/D conversion accuracy is guaranteed only when the impedance of the signal sources for analog input signals of the RX62T Group circuit is less than or equal to 3.0 kΩ. If a large external capacitance is provided in the case of conversion in single mode, the input load becomes only the actual internal input resistance (10 kΩ), so the impedance of the signal source becomes insufficient. However, since the circuit has become a low-pass filter, the rapid and large fluctuations in the analog signal produced by differentiation (for example, greater than 5 mV/µs) become impossible to track (Figure 28.11). Include a low-impedance buffer amplifier if high-rate analog signals are to be converted or conversion is to be in scan mode.

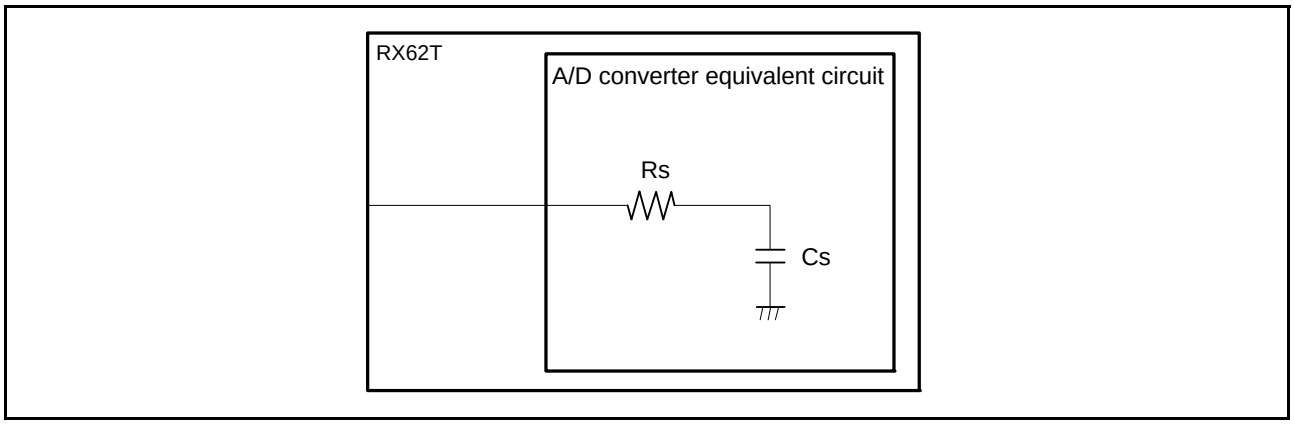


Figure 28.11 Equivalent Circuit for the Internal Circuit of Analog Input Pins

Table 28.10 Specifications of Analog Pins

Item		Min.	Max.	Unit
Permissible signal-source impedance		—	3.0	kΩ
Values in the equivalent circuits for the internal circuits of pins	Rs	—	10.0	kΩ
	Cs	—	8.0	pF

28.5.6 Factors Affecting Absolute Accuracy

Including a capacitor introduces ground coupling. A noisy ground can have a bad effect on absolute accuracy, so be sure to connect the AVSS0 pins and so on to an electrically stable ground.

Furthermore, a mounted filter circuit can interfere with digital-signal lines on the board, so take care to ensure that the design does not set up an antenna.

28.5.7 Ranges of Settings for Analog Power Supply and Other Pins

Using this LSI circuit with voltages beyond the ranges given below can have a bad effect on LSI reliability.

- Range for the setting of analog input voltages
  Keep voltages applied to analog input pins (ANn pins) within the range defined by VREFL0 ≤ VAN ≤ VREFH0.
- Power-Supply Pins (AVCC0 – AVSS0, AVCC – AVSS, and VCC – VSS)
  For the various power-supply pins (AVCC0 – AVSS0, AVCC – AVSS, and VCC – VSS), ensure that VCC ≤ AVCC0 = AVCC and AVSS0 = AVSS = VSS hold. If the 12-bit A/D converter is not in use, ensure that VCC = AVCC0 = AVCC and AVSS0 = AVSS = VSS.
- Range for the settings of VREFH0 and VREFL0
  Ensure that the voltages on the VREFH0 and VREFL0 pins satisfy VREFH0 ≤ AVCC0 and VREFL0 = AVSS0. When the A/D converters are not in use, ensure that VREFH0 = AVCC0 and VREFL0 = AVSS0.

28.5.8 Point for Caution Regarding Board Design

As far as possible, separate the analog circuits from the digital circuits in board design. Furthermore, do not allow the wiring runs for a signal of a digital circuit and a signal of an analog circuit to cross or be in each other's vicinity. Inductive coupling causes noise to be generated on the analog signals and has a bad effect on the results of analog conversion. Separate the signal lines for analog input pins (AN000 to AN003 and AN100 to AN103), the analog reference power supply pins (VREFH0 and VREFL0), and the analog power-supply voltage (AVCC0) away from digital circuitry by the analog ground (AVSS0). Furthermore, connect the analog ground (AVSS0) to the stabilized ground (VSS) on the board at a single point. Also, connect the 0.1-μF capacitors shown in Figure 28.12 to form the shortest possible closed loops between the respective pairs of power-supply lines.

28.5.9 Point for Caution Regarding Countermeasures for Noise

To prevent destruction of the circuits for the analog input pins by abnormal voltages such as excessively large surges, connect capacitors as shown in Figure 28.12 between AVCC0 and AVSS0, and between VREFH0 and VREFL0; also connect suitable protective circuits to the analog input pins (AN000 to AN003 and AN100 to AN103).

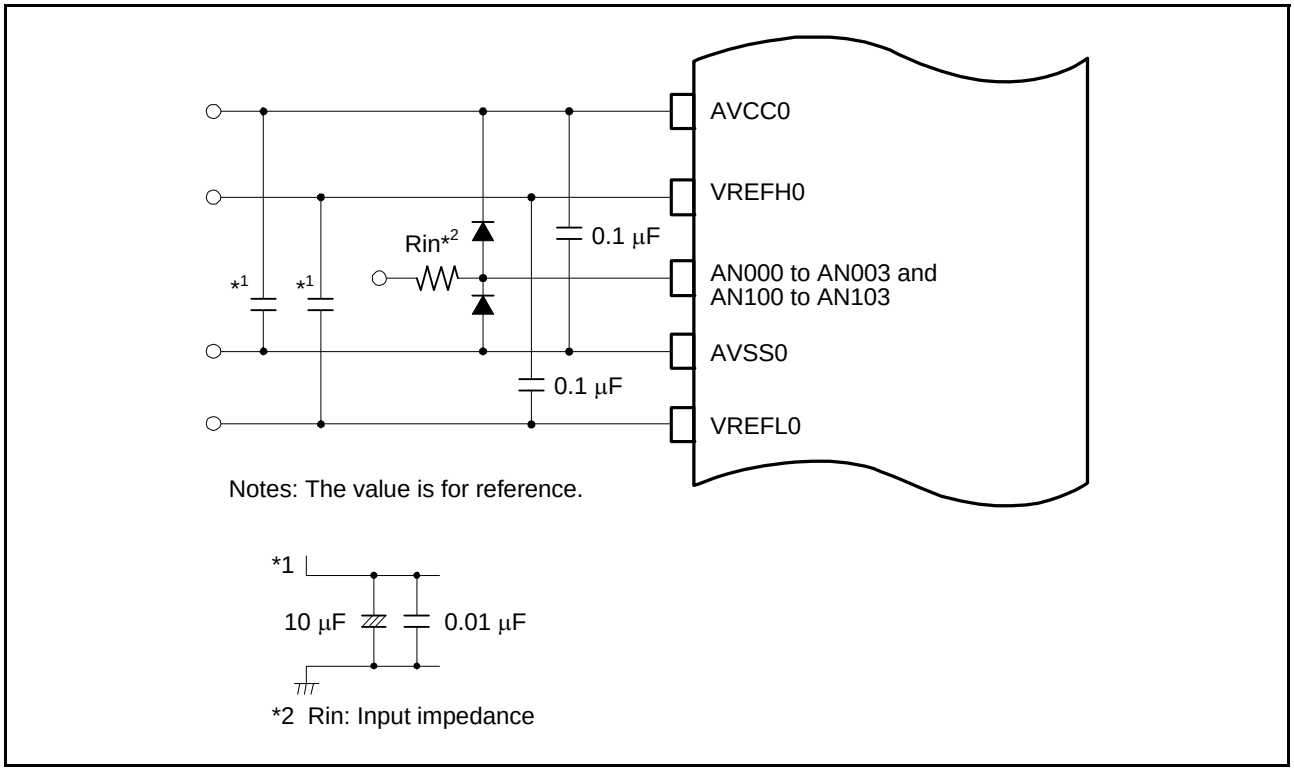


Figure 28.12 Example of a Protective Circuit for Analog Inputs

29. 10-Bit A/D Converter (ADA)

29.1 Overview

The RX62T Group includes a single successive-approximation-type 10-bit A/D converter. The converter is capable of handling up to 12 analog input channels.

The A/D converter has two kinds of operating modes, that are single mode which converts the analog input of the specified single channel for only once and scan mode which continuously converts the analog inputs of the specified channels up to 12.

Table 29.1 lists the specifications of the A/D converter and the Table 29.2 indicates its functions. Figure 29.1 shows a block diagram of the A/D converter.

Table 29.1 Specifications of A/D Converter

Item	Specifications
Number of units	One unit
Input channels	12 channels
A/D conversion method	Successive approximation method
Resolution	10 bits
Conversion time	1.0 μs per 1 channel (when operating A/D conversion clock ADCLK = 50 MHz, AVCC = 4.0 to 5.5 V) 2.0 μs per 1 channel (when operating A/D conversion clock ADCLK = 25 MHz, AVCC = 3.0 to 3.6 V)
A/D conversion clock	4 types: PCLK, PCLK/2, PCLK/4, PCLK/8
Operating modes	• Single mode: A/D conversion is to be performed for only once on the analog input of the specified single channel. • Scan mode Continuous scan mode: A/D conversion is to be performed sequentially on the analog inputs of the specified channels up to 12. One-cycle scan mode: A/D conversion is to be performed for one cycle on the analog inputs of the specified channels up to 12.
Conditions of A/D conversion start	• Software trigger • Conversion start trigger by the multi-function timer pulse unit (MTU3) or general PWM timer (GPT). • External trigger A/D conversion can be triggered from the ADTRG# pin.
Function	• Sample-and-hold function • Number of sampling state is adjustable. • Self-diagnostic functions
Interrupt source	• A/D conversion end interrupt (ADI0) request can be generated. • An ADI interrupt can activate data transfer controller (DTC).
Power-down function	Module stop state can be set.

Table 29.2 List of A/D Converter Function

Item			Function
Analog channels			AN0 to AN11
A/D conversion-start conditions	software	Software trigger	Possible
	External trigger	Trigger input pin	ADTRG#
	Trigger from MTU3	Compare-match with or input-capture to MTU0.TGRA	TRGA0N
		Compare-match with or input-capture to MTU1.TGRA	TRGA1N
		Compare-match with or input-capture to MTU2.TGRA	TRGA2N
		Compare-match with or input-capture to MTU3.TGRA	TRGA3N
		Compare-match with or input-capture to MTU4.TGRA, or underflow of the TCNT bit in MTU4 in complementary PWM mode	TRGA4N
		Compare-match with or input-capture to MTU6.TGRA	TRGA6N
		Compare-match with or input-capture to MTU7.TGRA, or underflow of the MTU7.TCNT in complementary PWM mode	TRGA7N
		Compare match with MTU0.TGRE	TRG0N
		Compare match between MTU4.TADCORA and MTU4. TCNT	TRG4AN
		Compare-match between MTU4.TADCORB and MTU4.TCNT	TRG4BN
		Compare-match between MTU4.TADCORA or MTU4.TADCORB and MTU4.TCNT	TRG4AN or TRG4BN
		Compare-match between MTU4.TADCORA or MTU4.TADCORB and MTU4.TCNT (when interrupt skipping function 2 is in use)	TRG4ABN
		Compare-match between MTU7.TADCORA and MTU7.TCNT	TRG7AN
		Compare-match between MTU7.TADCORB and MTU7.TCNT	TRG7BN
		Compare-match between MTU7.TADCORA or MTU7.TADCORB and MTU7.TCNT	TRG7AN or TRG7BN
		Compare-match between MTU7.TADCORA or MTU7.TADCORB and MTU7.TCNT (when interrupt skipping function 2 is in use)	TRG7ABN
	Trigger from GPT	Compare-match with GPT0.GTADTRA	GTADTRA0
		Compare-match with GPT0.GTADTRB	GTADTRB0
		Compare-match with GPT1.GTADTRA	GTADTRA1
		Compare-match with GPT1.GTADTRB	GTADTRB1
		Compare-match with GPT2. GTADTRA	GTADTRA2
		Compare-match with GPT2.GTADTRB	GTADTRB2
		Compare-match with GPT3.GTADTRA	GTADTRA3
		Compare-match with GPT3.GTADTRB	GTADTRB3
A/D conversion-start conditions	Trigger from GPT	Compare-match with GPT0.GTADTRA or with GPT0.GTADTRB	GTADTRA0 or GTADTRB0
		Compare-match with GPT1.GTADTRA or with GPT1.GTADTRB	GTADTRA1 or GTADTRB1
		Compare-match with GPT2.GTADTRA or with GPT2.GTADTRB	GTADTRA2 or GTADTRB2
		Compare-match with GPT3.GTADTRA or with GPT3.GTADTRB	GTADTRA3 or GTADTRB3
Interrupt			ADI interrupt
Setting of the module-stop function*1			MSTPCRA. MSTPA23 bit

Note 1. See section 9, Low Power Consumption, for details.

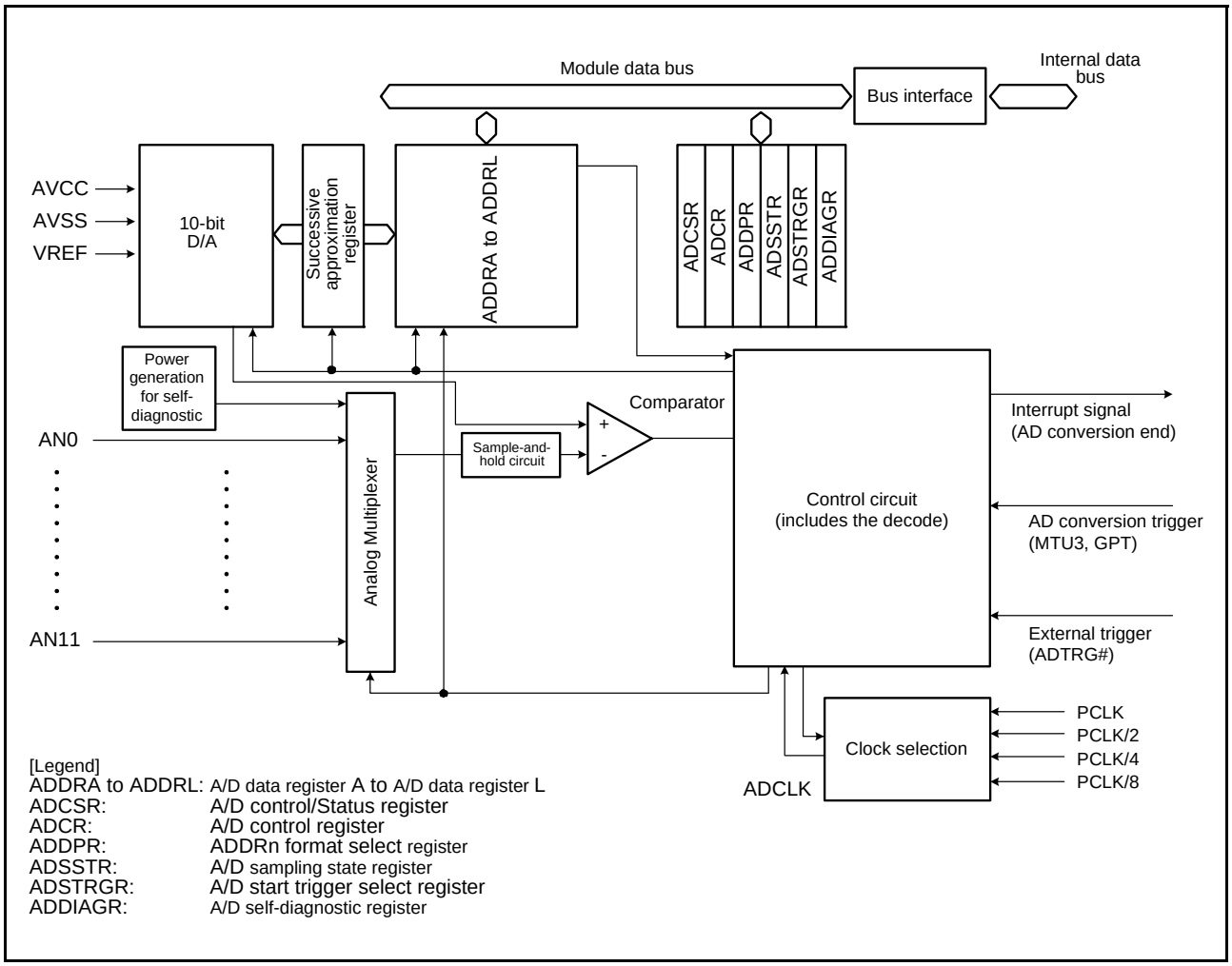


Figure 29.1 The Block Diagram of the A/D Converter

Input pins for use with the A/D converter are listed inTable 29.3.

Table 29.3 Input Pin for A/D Converter

Module Symbol	Pin	Input	Function
AD0	AN0 to AN11	Input	Analog input pins
	ADTRG#	Input	External trigger input pin for starting A/D conversion
	AVCC	Input	Power pin for the analog section
	AVSS	Input	Ground pin for the analog section
	VREF	Input	Reference-voltage pin for the A/D converter

29.2 Register Descriptions

Table 29.4 lists the registers of the A/D converter.

Table 29.4 Registers of A/D Converter

Module Symbol	Register Name	Register Symbol	Value after Reset	Address	Access Size
AD0	A/D data register A	ADDRA	0000h	0008 8040h	16
	A/D data register B	ADDRB	0000h	0008 8042h	16
	A/D data register C	ADDRC	0000h	0008 8044h	16
	A/D data register D	ADDRD	0000h	0008 8046h	16
	A/D data register E	ADDRE	0000h	0008 8048h	16
	A/D data register F	ADDRF	0000h	0008 804Ah	16
	A/D data register G	ADDRG	0000h	0008 804Ch	16
	A/D data register H	ADDRH	0000h	0008 804Eh	16
	A/D data register I	ADDRI	0000h	0008 8060h	16
	A/D data register J	ADDRJ	0000h	0008 8062h	16
	A/D data register K	ADDRK	0000h	0008 8064h	16
	A/D data register L	ADDRL	0000h	0008 8066h	16
	A/D control/status register	ADCSR	x0h	0008 8050h	8
	A/D control register	ADCR	00h	0008 8051h	8
	A/D sampling state register	ADSSTR	19h	0008 805Bh	8
	A/D self-diagnostic register	ADDIAGR	00h	0008 805Dh	8
	A/D start trigger select register	ADSTRGR	00h	0008 8070h	8
	ADDRn format select register	ADDPR	00h	0008 8072h	8

29.2.1 A/D Data Register n (ADDRn) (n = A to L)

Address: ADDRA 0008 8040h, ADDRB 0008 8042h, ADDRC 0008 8044h, ADDRD 0008 8046h
ADDRE 0008 8048h, ADDRF 0008 804Ah, ADDRG 0008 804Ch, ADDRH 0008 804Eh
ADDRI 0008 8060h, ADDRJ 0008 8062h, ADDRK 0008 8064h, ADDRL 0008 8066Eh

ADDPR.DPSEL bit = 1, DDPPRC.DPSEL bit = 0 (The value has 10-bit accuracy and is padded at the MSB end)

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	AD9	AD8	AD7	AD6	AD5	AD4	AD3	AD2	AD1	AD0	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit	Function	R/W
b5 to b0	—	Reserved	These bits are always read as 0. Writing to those bits has no effect.	R
b15 to b6	AD9 to AD0	Converted value[9:0]	10-bit result of A/D conversion	R

ADDPR.DPSEL bit = 1, ADDPR.DPPRC bit = 1 (The value has 8-bit accuracy and is padded at the MSB end)

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	AD9	AD8	AD7	AD6	AD5	AD4	AD3	AD2	—	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit	Function	R/W
b7 to b0	—	Reserved	These bits are always read as 0. Writing to those bits has no effect.	R
b15 to b8	AD9 to AD2	Converted value [9:2]	Higher-order 8 bits of the 10-bit result of A/D conversion	R

ADDPR.DPSEL bit = 0, ADDPR.DPPRC bit = 1 (The value has 10-bit accuracy and is padded at the LSB end)

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	AD9	AD8	AD7	AD6	AD5	AD4	AD3	AD2	AD1	AD0
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit	Function	R/W
b9 to b0	AD9 to AD0	Converted value[9:0]	10-bit result of A/D conversion	R
b15 to b10	—	Reserved	These bits are always read as 0. Writing to those bits has no effect.	R

ADDPR.DPSEL bit = 0, ADDPR.DPPRC bit = 1 (The value has 10-bit accuracy and is padded at the LSB end)

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	AD9	AD8	AD7	AD6	AD5	AD4	AD3	AD2
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit	Function	R/W
b7 to b0	AD9 to AD2	Converted value[9:2]	Higher-order 8 bits of the 10-bit result of A/D conversion	R
b15 to b8	——	Reserved	These bits are always read as 0. Writing to those bits has no effect.	R

The ADDRn registers are 16-bit read-only registers which store the results of A/D conversion on the respective channels. Table 29.5 lists the analog input channels and corresponding ADDRn registers.
10-bit data can be relocated by setting the DPSEL bit in ADDPR.
Also, the precision (in bits) of the stored data can be set by the DPPRC bit in ADDPR.

Table 29.5 Analog Input Channels and Corresponding ADDRn Registers

Analog Input Channel	ADDRn Register
AN0	ADDRA
AN1	ADDRB
AN2	ADDRC
AN3	ADDRD
AN4	ADDRE
AN5	ADDRF
AN6	ADDRG
AN7	ADDRH
AN8	ADDRI
AN9	ADDRJ
AN10	ADDRK
AN11	ADDRL

29.2.2 A/D Control/Status Register (ADCSR)

Address: 0008 8050h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	ADIE	ADST	—	CH[3:0]			
Value after reset:	0	0	0	0	0	0	0	0

x: Undefined

Bit	Symbol	Bit Name	Description		R/W
b3 to b0	CH[3:0]	Channel Select*1	Single mode (ADCR.MODE[1:0] = 00b) b3 b0 0 0 0 0: AN0 0 0 0 1: AN1 0 0 1 0: AN2 0 0 1 1: AN3 : : 1 0 1 1: AN11 Settings other than above are prohibited.	Scan mode (ADCR.MODE[1:0] = 10b or 11b) b3 b0 0 0 0 0: AN0 0 0 0 1: AN0 and AN1 0 0 1 0: AN0 to AN2 0 0 1 1: AN0 to AN3 : : 1 0 1 1: AN0 to AN11 Settings other than above are prohibited.	R/W
b4	—	Reserved	This bit is always read as 0. The write value should always be 0.		R/W
b5	ADST	A/D Start	0: Stops A/D conversion 1: Starts A/D conversion		R/W
b6	ADIE	A/D Interrupt Enable	0: ADI interrupt is disabled by completing A/D conversion 1: ADI interrupt is enabled by completing A/D conversion		R/W
b7	—	Reserved	The read value is undefined. The write value should always be 0.		R/W

Note 1. The PORTn.DDR.Bi bit for the analog input should be set to 0 (input port) and the PORTn.ICR.Bi bit should be set to 0 (disabling the input buffer and fixing the input signal to the high level). For details, see section 15, I/O Ports. (n = 6, 5, i = 5 to 0)

ADCSR controls the A/D conversion operations.
Set the CH[3:0] and ADIE bits while the ADST bit is 0.

CH[3:0] Bits (Channel Select)

These bits select analog input channels that allow A/D conversion.

- Single mode (ADCR.MODE[1:0] bits = 00b)
  Select the single analog input channel that allows A/D.
- Scan mode (ADCR.MODE[1:0] bits = 10b or 11b)
  Select analog input channels up to 12 that allow A/D conversion.

ADST Bit (A/D Start)

The ADST bit starts/stops A/D conversion.
Before setting the ADST bit to 1, complete the setting for A/D conversion clock and the operation mode.

[Setting conditions]

- When 1 is written by software
- Detection of the trigger selected by the ADSTRGR.ADSTRS [4:0] bits

[Clearing conditions]

- When 0 is written by software
- The A/D conversion is completed in single mode
- The A/D conversion is completed on every selected channel in one-cycle scan mode.

ADIE Bit (A/D Interrupt Enable)

The ADIE bit enables/disables the A/D conversion end interrupt (ADI).

29.2.3 A/D Control Register (ADCR)

Address: 0008 8051h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	CKS[1:0]		MODE[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1, b0	MODE[1:0]	Operation Mode Select	b1 b0 0 0: Single mode 0 1: Setting prohibited 1 0: Continuous scan mode 1 1: One-cycle scan mode	R/W
b3, b2	CKS[1:0]	Clock Select	b3 b2 0 0: PCLK/8 0 1: PCLK/4 1 0: PCLK/2 1 1: PCLK	R/W
b7 to b4	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

ADCR enables setting for an A/D conversion, an operating mode, and A/D conversion clock mode.
Set ADCR while the ADST bit in ADCSR is 0.

MODE[1:0] Bits (Operating Mode Select)

These bits select the A/D conversion operation mode.

CKS[1:0] Bits (Clock Select)

These bits set the frequency of the A/D conversion clock (ADCLK) and thus select the A/D conversion time.
Set the frequency of ADCLK above 4 MHz. When AVCC is in the range from 3.0 V to 3.6 V, set the frequency of ADCLK below 25 MHz.
For details, see section 29.3.3, Input Sampling and A/D Conversion Time.

29.2.4 A/D start trigger select register (ADSTRGR)

Address: 0008 8070h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	ADSTRS[4:0]				
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b4 to b0	ADSTRS[4:0]	A/D start trigger select	Bits 0 to 4 select a peripheral module as the source for activation of the A/D converter. See Table 29.6 for the correspondence between settings and activation sources.	R/W
b7 to b5	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

Table 29.6 A/D Activation Source Selection (1 / 2)

Activation source	Source	Start condition	ADSTRS [4]	ADSTRS [3]	ADSTRS [2]	ADSTRS [1]	ADSTRS [0]
Software	ADST	Set the ADST bit in ADCSR	—	—	—	—	—
External pin	ADTRG#*1	External trigger	0	0	0	0	0
MTU3	TRGA0N	Compare-match with or input-capture to MTU0.TGRA	0	0	0	0	1
	TRGA1N	Compare-match with or input-capture to MTU1.TGRA	0	0	0	1	0
	TRGA2N	Compare-match with or input-capture to MTU2.TGRA	0	0	0	1	1
	TRGA3N	Compare-match with or input-capture to MTU3.TGRA	0	0	1	0	0
	TRGA4N	Compare-match with or input-capture to MTU4.TGRA, or underflow of the TCNT bits in MTU4 in complementary PWM mode	0	0	1	0	1
	TRGA6N	Compare-match with or input-capture to MTU6.TGRA	0	0	1	1	0
	TRGA7N	Compare-match with or input-capture to MTU7.TGRA, or underflow of the TCNT bits in MTU7 in complementary PWM mode	0	0	1	1	1
	TRG0N	Compare-match with MTU0.TGRE	0	1	0	0	0
	TRG4AN	Compare-match with MTU4.TADCORA and MTU4.TCNT	0	1	0	0	1
	TRG4BN	Compare-match between MTU4.TADCORB and MTU4.TCNT	0	1	0	1	0
	TRG4AN or TRG4BN	Compare-match between MTU4.TADCORA or MTU4.TADCORB and MTU4.TCNT	0	1	0	1	1
	TRG4ABN	Compare-match between MTU4.TADCORA or MTU4.TADCORB and MTU4.TCNT (when interrupt skipping function 2 is in use)	0	1	1	0	0
	TRG7AN	Compare-match between MTU7.TADCORA and MTU7.TCNT	0	1	1	0	1
	TRG7BN	Compare-match between MTU7.TADCORB and MTU7.TCNT	0	1	1	1	0
	TRG7AN or TRG7BN	Compare-match between MTU7.TADCORA or MTU7.TADCORB and MTU7.TCNT	0	1	1	1	1
	TRG7ABN	Compare-match between MTU7.TADCORA or MTU7.TADCORB and MTU7.TCNT (when interrupt skipping function 2 is in use)	1	0	0	0	0
GPT	GTADTRA0	Compare-match with GPT0.GTADTRA	1	0	0	0	1
	GTADTRB0	Compare-match with GPT0.GTADTRB	1	0	0	1	0
	GTADTRA1	Compare-match with GPT1.GTADTRA	1	0	0	1	1
	GTADTRB1	Compare-match with GPT1.GTADTRB	1	0	1	0	0
	GTADTRA2	Compare-match with GPT2.GTADTRA	1	0	1	0	1
	GTADTRB2	Compare-match with GPT2.GTADTRB	1	0	1	1	0
	GTADTRA3	Compare-match with GPT3.GTADTRA	1	0	1	1	1
	GTADTRB3	Compare-match with GPT3.GTADTRB	1	1	0	0	0
	GTADTRA0 or GTADTRB0	Compare-match with GPT0.GTADTRA or with GPT0.GTADTRB	1	1	0	0	1

Table 29.6 A/D Activation Source Selection (2 / 2)

Activation source	Source	Start condition	ADSTRS [4]	ADSTRS [3]	ADSTRS [2]	ADSTRS [1]	ADSTRS [0]
GPT	GTADTRA1 or GTADTRB1	Compare-match with GPT1.GTADTRA or with GPT1.GTADTRB	1	1	0	1	0
	GTADTRA2 or GTADTRB2	Compare-match with GPT2.GTADTRA or with GPT2.GTADTRB	1	1	0	1	1
	GTADTRA3 or GTADTRB3	Compare-match with GPT3.GTADTRA or GPT3.GTADTRB	1	1	1	0	0

Note 1. When an ADTRG# signal is selected as a trigger to start A/D conversion, set the PORTn.DDR.Bi bit to 0 (selecting input operation) and the PORTn.ICR.Bi bit to 1 (enabling the input buffer for the given pin). For details, see section 15, I/O Ports.

29.2.5 ADDRn Format Select Register (ADDPR) (n = A to L)

Address: 0008 8072h

	b7	b6	b5	b4	b3	b2	b1	b0
	DPSEL	—	—	—	—	—	—	DPPRC
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	DPPRC	Accuracy Specification	0: Values stored in the A/D registers have 10-bit accuracy. 1: Values stored in the A/D registers have 8-bit accuracy.	R/W
b6 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7	DPSEL	ADDRn Format Select	0: A/D data is padded at the LSB end. 1: A/D data is padded at the MSB end.	R/W

ADDPR selects the placement of data in the A/D data registers.

DPPRC Bit (Accuracy Specification)

This bit selects storage of the results of A/D conversion in the data registers with 8- or 10-bit accuracy.

DPSEL Bit (ADDRn Format Select)

The DPSEL bit selects whether data in the A/D data register n (ADDRn) is padded at the LSB or MSB end.

29.2.6 A/D Self-Diagnostic Register (ADDIAGR)

Address: 0008 805Dh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	DIAG[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1, b0	DIAG[1:0]	Self-Diagnostic	b1 b0 0 0: Self-diagnostic function is off. 0 1: A/D conversion of Vref x 0 voltage value is enabled. 1 0: A/D conversion of Vref x 1/2 voltage value is enabled. 1 1: A/D conversion of Vref x 1 voltage value is enabled.	R/W
b7 to b2	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

ADDIAGR specifies the self-diagnostic function and the voltage for use with the function.
Specify ADDIAGR while the ADCSR.ADST bit is 0.

DIAG[1:0] Bits (Self-Diagnostic)

The self-diagnostic function is used to detect faults in the A/D converter. The setting selects whether the function is or is not in use, and if it is, whether the internally generated voltage is to be derived as Vref x 0, Vref x 1/2, or Vref x 1.
To perform the self-diagnostic, select the voltage value by the ADDIAGR.DIAG[1:0] bits and start the A/D conversion in the procedure below.

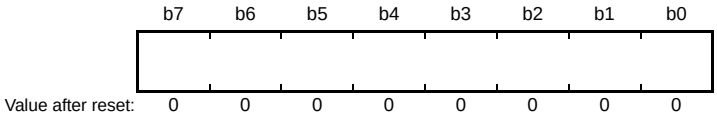
- Single mode (the ADCR.MODE[1:0] bits = 00)
- Analog input AN0 is only enabled (the ADCSR.CH[3:0] bits = 0000)*
- A/D conversion is started by software. (the ADCR.TRGS[2:0] bits = 000)

After A/D conversion ends, the conversion result is stored in the A/D data register A (ADDRA). Then, whether the conversion result is within the normal range (normal) or not (error) can be found out from the values read from ADDRA by software. The execution time required for self-diagnostic is the same as that for A/D conversion of one channel.

Note: • Set AN0 as the input channel to perform self-diagnosis of A/D converter. Since selection of the data register to store the result of conversion is required, the AN0 pin itself is disabled.

29.2.7 A/D Sampling State Register (ADSSTR)

Address: 0008 805Bh



ADSSTR is an 8-bit readable/writable register that is used to set the sampling time for analog inputs.
Sampling time is adjustable when the signal source impedance of analog input is high and the sampling time is insufficient or the speed of A/D conversion clock (ADCLK) is low.
Set the value of 02h or larger.
Ensure to rewrite this register while the A/D conversion is stopped (the ADST bit in ADCSR = 0) in order to prevent incorrect operation.
For details, see section 29.3.3, Input Sampling and A/D Conversion Time.

29.3 Operation

The A/D converter has two operating modes: single mode and scan mode.
In single mode, A/D conversion is to be performed for only once on the analog input of the specified single channel.
In scan mode, A/D conversion is to be performed sequentially on the analog inputs of the specified channels up to 12.
Two types of scan mode are provided, that is, continuous san mode where A/D conversion is repeatedly performed and one-cycle scan mode where A/D conversion is performed for the specified channels for one cycle.

29.3.1 Single Mode

In single mode, A/D conversion is to be performed for only once on the analog input of the specified single channel as below.

1. A/D conversion for the selected channel is started when the ADST bit in ADCSR is set to 1 (A/D conversion start) by software, MTU3, GPT, or an external trigger input.
2. When A/D conversion is completed, the A/D conversion result is stored into the corresponding A/D data register (ADDRn) of the channel.
3. When A/D conversion is completed, if the ADIE bit in ADCSR is set to 1 (A/D interrupt enable by completing A/D conversion), an ADI interrupt request is generated.
4. The ADST bit in the ADCSR remains at 1 during A/D conversion, and is automatically cleared to 0 when A/D conversion ends. Then the A/D converter enters a wait state.
5. If the ADST bit in the ADCSR is cleared to 0 during A/D conversion (A/D conversion stop), A/D conversion stops and the A/D converter enters a wait state.

Figure 29.2 shows an example of operation when AN1 is selected as an analog input.

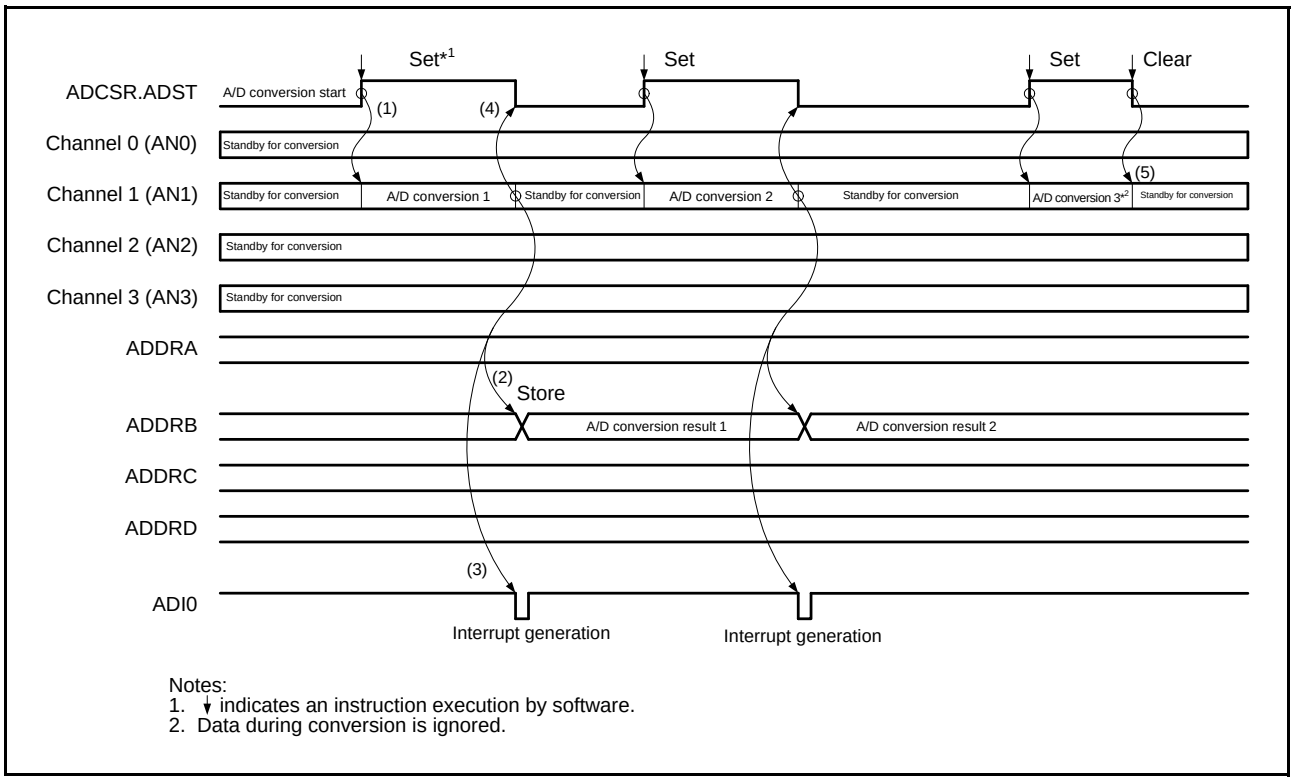


Figure 29.2 Example of A/D Converter Operation (Single Mode)

29.3.2 Scan Mode

In scan mode, A/D conversion is to be performed sequentially on the analog inputs of the specified channels up to 12. Two types of scan mode are provided, that is, continuous scan mode where A/D conversion is repeatedly performed and one-cycle scan mode where A/D conversion is performed for the specified channels for one cycle.

29.3.2.1 Continuous Scan Mode

In continuous scan mode, A/D conversion is to be performed sequentially on the analog inputs of the specified channels as below.

1. When the ADST bit in ADCSR is set to 1 (A/D conversion start) by software, MTU3, GPT, or an external trigger input, A/D conversion starts on the first channel in the specified channel group.
2. When A/D conversion for each channel is completed, the A/D conversion result is stored into the corresponding A/D data registers n (ADDRn) (n = A to L).
3. When A/D conversion of all selected channels is completed, if the ADIE bit in ADCSR is set to 1 (A/D interrupt enable by completing A/D conversion), an ADI interrupt request is generated. A/D converter starts A/D conversion from the first channel.
4. The ADST bit in the ADCSR is not cleared automatically, and steps 2 to 3 are repeated as long as the ADST bit remains set to 1 (A/D conversion start). When the ADST bit is cleared to 0 (A/D conversion stop), A/D conversion stops and the A/D converter enters a wait state.
5. If the ADST bit in the ADCSR is later set to 1 (A/D conversion start), A/D conversion starts again from the first channel in the group.

Figure 29.3 shows an example of A/D conversion when three channels (AN0 to AN2) are selected for analog input.

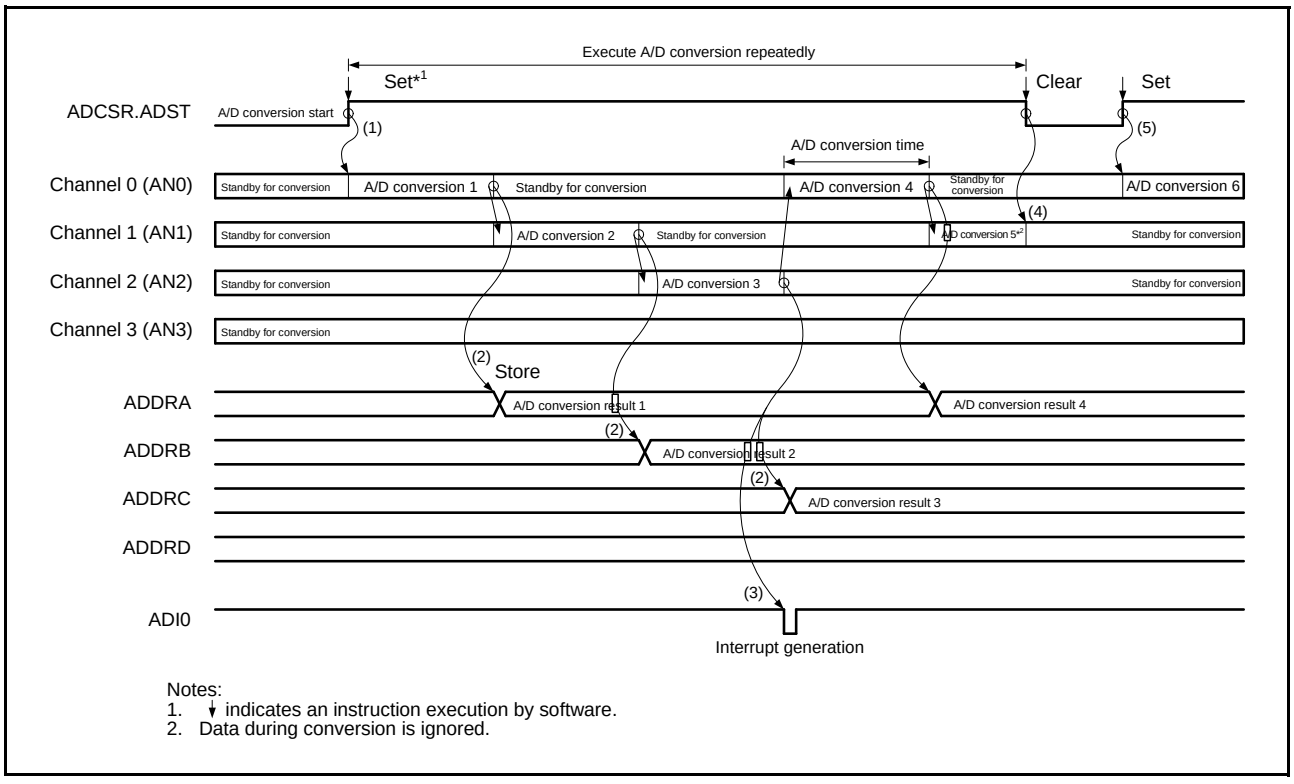


Figure 29.3 Example of A/D Converter Operation (Continuous Scan Mode)

29.3.2.2 One-Cycle Scan Mode

In one-cycle scan mode, A/D conversion is to be performed for one cycle on the analog inputs of the specified channels as below.

1.When the ADST bit in ADCSR is set to 1 (A/D conversion start) by software, MTU3, GPT, or an external trigger input, A/D conversion starts on the first channel in the specified channel group.

2.When A/D conversion for each channel is completed, the A/D conversion result is stored into the corresponding A/D data registers (ADDRn) (n = A to L).

3.When A/D conversion of all selected channels is completed, if the ADIE bit in ADCSR is set to 1 (A/D interrupt enable by completing A/D conversion), an ADI interrupt request is generated.

4.The ADST bit in ADCSR remains at 1 (A/D conversion start) during A/D conversion, and is automatically cleared to 0 when A/D conversion of all selected channels end. The A/D converter enters a wait state.

Figure 29.4 shows an example of A/D conversion when three channels (AN0 to AN2) are selected for analog input.

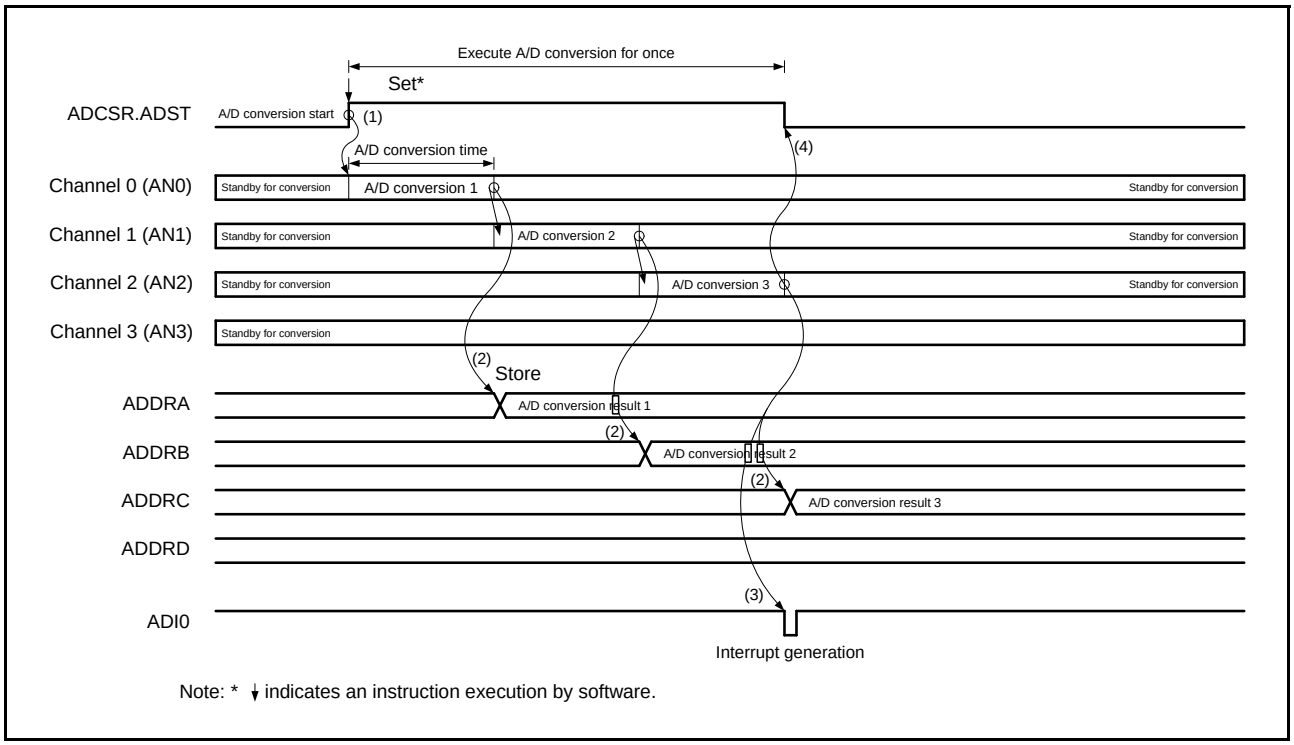
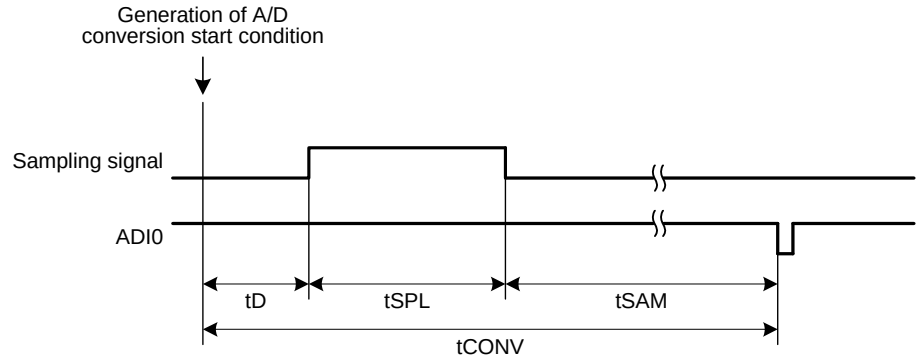


Figure 29.4 Example of A/D Converter Operation (One-Cycle Scan Mode)

29.3.3 Input Sampling and A/D Conversion Time

The A/D converter samples the analog input when the A/D conversion start delay time (tD) passes after the conditions of A/D conversion start are generated by software, MTU3, GPT, or an external trigger, then starts A/D conversion.
Figure 29.5 shows the A/D conversion timing.
The A/D conversion time (tCONV) directly after the generation of the A/D conversion start condition includes the A/D conversion start delay time (tD), the input sampling time (tSPL), and the successive conversion time (tSAM). The subsequent A/D conversion time (tCONV) includes tSPL and tSAM.
The input sampling time (tSPL) is the time charging of the input capacitance of the A/D converter's sample-and-hold circuit takes. If the impedance of the signal source is high and the sampling time is insufficient or the A/D conversion clock (ADCLK) is running at low speed, the sampling time can be adjusted by using the ADSSTR.
The successive conversion time (tSAM) is fixed at 25 cycles of ADCLK.
Table 29.6 lists the sample of ADSSTR settings and Table 29.7 lists the A/D conversion time.



[Legend]
tD: A/D conversion start delay time
tSPL: Input sampling time
tSAM: Successive conversion time
tCONV: A/D conversion time

Figure 29.5 A/D Conversion Timing

Table 29.7 Example of ADSSTR Settings

Example of Setting	Setting Range	Sampling Time*1
Standard (initial value)	19h	0.5 µs (When PCLK = ADCLK = 50 MHz)
Analog input signal impedance is high and the sampling time may be insufficient	1Ah to FFh	Example: FFh 5.1 µs (When PCLK = ADCLK = 50 MHz)
Input sampling time is less than the initial value when ADCLK is below 50 MHz	02h to 18h	Example: 14h 0.5 µs (When PCLK = ADCLK = 40 MHz)

Note 1. Set the sampling time ≥ 0.5 µs. Sampling time is shown as the formula below.

$$\text{Sampling time (µs)} = \frac{\text{Setting value of ADSSTR}}{\text{ADCLK (MHz)}}$$

Table 29.8 A/D Conversion Time

Item	Symbol	Formula	
		min	max
A/D conversion start delay time (1)	tD	$\frac{3}{\text{PCLK (MHz)}}$	$\frac{1}{\text{ADCLK (MHz)}} + \frac{4}{\text{PCLK (MHz)}}$
Input sampling time (2)	tSPL	$\frac{\text{Setting value of ADSSTR}}{\text{ADCLK (MHz)}}$	
Successive conversion time (3)	tSAM	$\frac{25}{\text{ADCLK (MHz)}}$	
A/D conversion time*1	tCONV	(1) + (2) + (3)	
A/D conversion time*2	tCONV	(2) + (3)	

Notes: 1. A/D conversion time in single mode and scan mode (first round)
2. A/D conversion time in scan mode (after the second round)

The examples of the calculation of A/D conversion times are listed below.

When PCLK = ADCLK = 50 MHz, ADSSTR = 19h, and the conversion is the second round in scan mode,
A/D conversion time (tCONV) = ADSSTR/ADCLK + 25/ADCLK
= 25/50 MHz + 25/50 MHz
= 0.5 µs + 0.5 µs
= 1.0 µs

When PCLK = ADCLK = 40 MHz, ADSSTR = 14h, and conversion is the first (min.) round in scan mode,
A/D conversion time (tCONV) = 3/PCLK + ADSSTR/ADCLK + 25/ADCLK
= 3/40 MHz + 20/40 MHz + 25/40 MHz
= 0.075 µs + 0.5 µs + 0.625 µs
= 1.2 µs

29.3.4 A/D Converter Activation by External Triggers

External trigger signals (ADTRG#) are capable of starting A/D conversion.
When the setting of the ADSTRGR.ADSTRS[4:0] bits is 00000b (specifying ADTRG# as a trigger), a falling edge on the ADTRG# pin leads to setting of the ADST (A/D conversion start) bit in ADCSR to 1 and thus starts A/D conversion. Figure 29.6 shows the timing.
Take note that if the external trigger input is already at the low-level, selecting the external trigger may generate a falling edge in the internal signal and thus start A/D conversion.

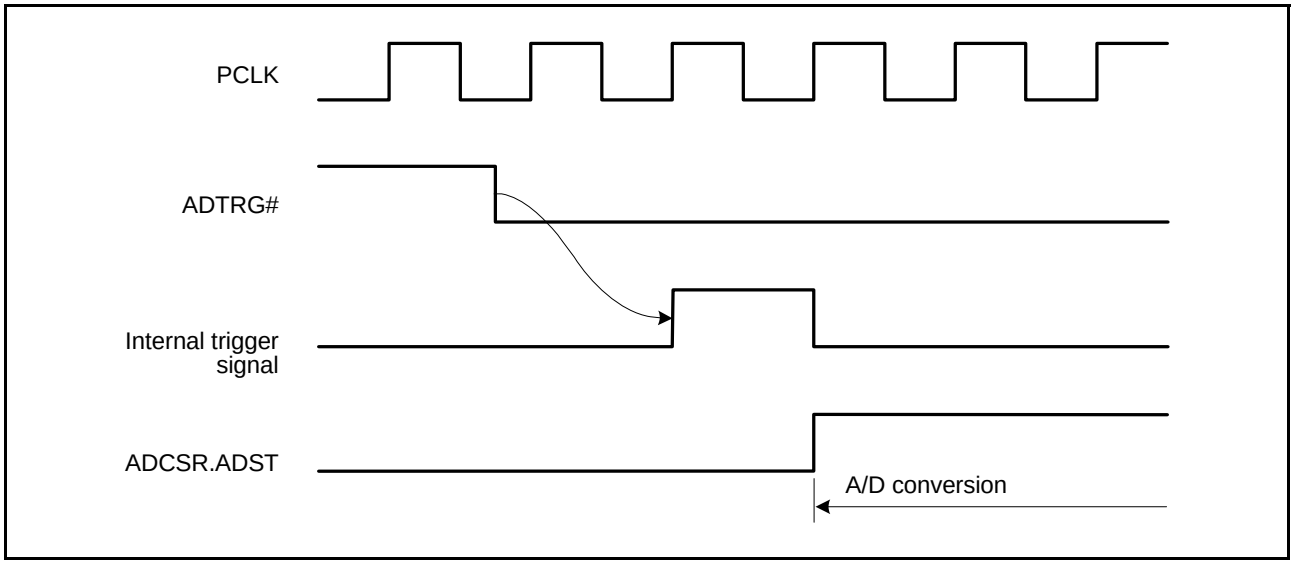


Figure 29.6 Timing of Activation by an External Trigger

29.3.5 Activation by the MTU3 and GPT Modules

A/D conversion can be started by requests for A/D conversion from the MTU3 and GPT as interval timers.
For the MTU3 or GPT to start the A/D converter, the ADSTRGR.ADSTRS[4:0] (A/D conversion start trigger) bits must be set accordingly. Once this is done, the ADCSR.ADST (A/D conversion start) bit is set to 1 in response to a request for A/D conversion from an interval timer of the MTU3 or GPT module, and A/D conversion starts. Timing between setting of the ADST bit to 1 and the start of A/D conversion is the same as when software is used to set the ADST bit.

29.4 Interrupt Source

The A/D converter generates an A/D conversion end interrupt (ADI0) at the end of A/D conversion while the ADIE bit in ADCSR is set to 1 (after ADI interrupt is enabled by completing A/D conversion).
The data transfer controller (DTC) can be activated by an ADI interrupt. Using an ADI interrupt to allow the DTC to read the converted data enables continuous conversion without burden on the CPU.

Table 29.9 A/D Converter Interrupt Source

Name	Interrupt Source	Interrupt Status Flag	DTC Activation
ADI0	A/D conversion end	ICU.IR98.IR	Possible

29.5 A/D Conversion Accuracy Definitions

The RX62T Group's A/D conversion accuracy definitions are given below.

- Resolution
  The number of A/D converter digital output codes
- Quantization error
  The deviation inherent in the A/D converter, given by 1/2 LSB (Figure 29.7)
- Offset error
  The deviation of the analog input voltage value from the ideal A/D conversion characteristic when the digital output changes from the minimum voltage value 0000000000b (000h) to 0000000001b (001h) (Figure 29.8)
- Full-scale error
  The deviation of the analog input voltage value from the ideal A/D conversion characteristic when the digital output changes from 1111111110b (3FEh) to 1111111111b (3FFh) (Figure 29.8)
- Nonlinearity error
  The error with respect to the ideal A/D conversion characteristic between the zero voltage and the full-scale voltage. Does not include the offset error, full-scale error, or quantization error (Figure 29.8).
- Absolute accuracy
  The deviation between the digital value and the analog input value. Includes the offset error, full-scale error, quantization error, and nonlinearity error.

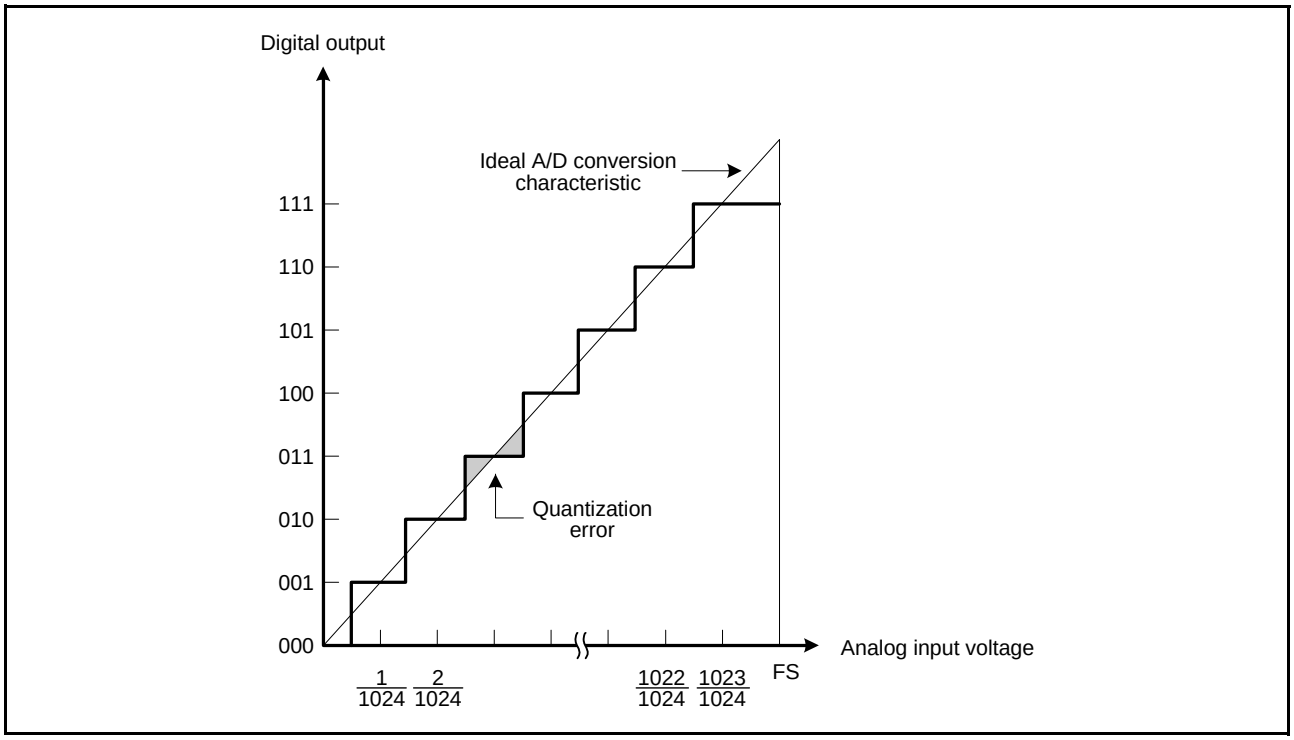


Figure 29.7 A/D Conversion Accuracy Definitions (1)

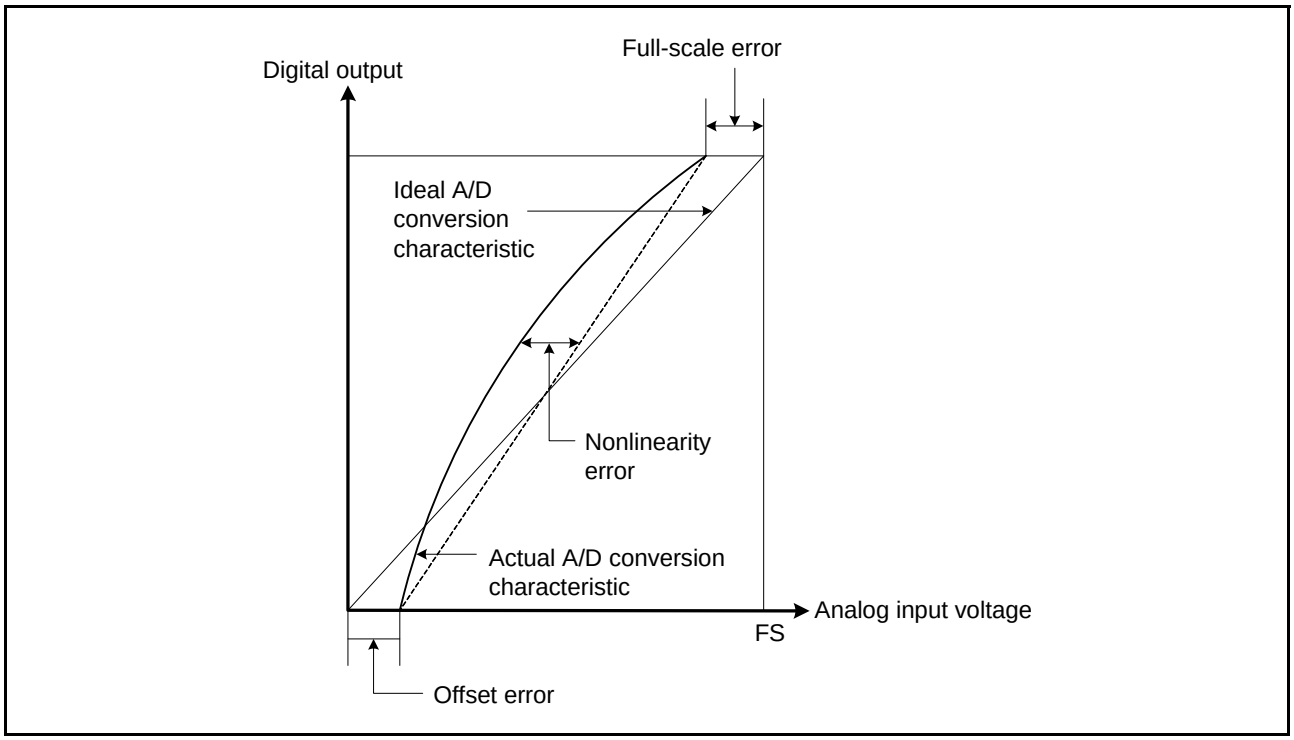


Figure 29.8 A/D Conversion Accuracy Definitions (2)

29.6 Usage Notes

29.6.1 Module Stop Function Setting

Operation of the A/D converter can be disabled or enabled using the module stop control register. The initial setting is for operation of the A/D converter to be halted. Register access is enabled by clearing the module stop state. For details, see section 9, Low Power Consumption.

29.6.2 Notes on Disabling A/D Conversion

To disable A/D conversion when an external trigger or timer has been selected as the condition for starting A/D conversion, set the ADST bit in ADCSR to 0 (to stop A/D conversion).

29.6.3 Notes on Restarting A/D Conversion

Stopping analog input to the A/D converter by clearing the ADST bit in ADCSR to 0, requires one cycle of the ADCLK. If A/D conversion is to be restarted right after the ADST bit in ADCSR was set to 0, set the ADST bit in ADCSR to 1 after one cycle of the ADCLK has elapsed.

29.6.4 Notes on Entering Power-Down States

When the RX62T Group enters the module stop state or software standby mode with A/D conversion enabled, the analog power supply current is the same as it is during A/D conversion. If the analog power supply current needs to be reduced in the module stop state or software standby mode, disable A/D conversion. To do so, set the ADST bit in ADCSR to 0, and allow time for disabling of the analog input to the A/D converter.
Follow the procedure given below to ensure that this time is secured.

(1) Clear the ADCSR.ADST bit to 0.
(2) Set the ADCR.CKS[1:0] bits to 11b (PCLK).
(3) After confirming that the A/D converter has been disabled, place the LSI in the module stop state or software standby mode.

29.6.5 Permissible Impedance of Signal Sources

To realize high-speed conversion 1.0 µs, the A/D conversion accuracy is guaranteed only when the impedance of the signal sources for analog input signals of the RX62T Group circuit is less than or equal to 1.0 kΩ. If a large external capacitance is provided in the case of conversion in single mode, the input load becomes only the actual internal input resistance (8 kΩ), so the impedance of the signal source becomes insufficient. However, since the circuit has become a low-pass filter, the rapid and large fluctuations in the analog signal produced by differentiation (for example, greater than 5 mV/µs) become impossible to track (Figure 29.9). Include a low-impedance buffer amplifier if high-rate analog signals are to be converted or conversion is to be in scan mode.

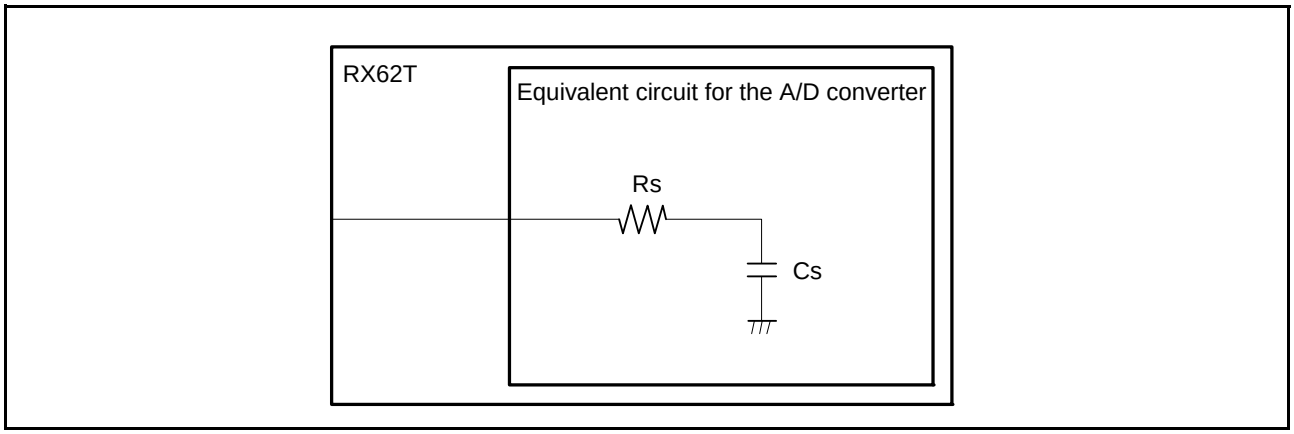


Figure 29.9 Equivalent Circuit for the Internal Circuit of Analog Input Pins

Table 29.10 Specifications of Analog Pins

Item		Min.	Max.	Unit
Permissible signal-source impedance		—	1.0	kΩ
Values in the equivalent circuits for the internal circuits of pins	Rs	—	8.0	kΩ
	Cs	—	7.0	pF

29.6.6 Factors Affecting Absolute Accuracy

Including a capacitor introduces ground coupling. A noisy ground can have a bad effect on absolute accuracy, so be sure to connect the AVSS pins and so on to an electrically stable ground.
Furthermore, a mounted filter circuit can interfere with digital-signal lines on the board, so take care to ensure that the design does not set up an antenna.

29.6.7 Ranges of Settings for Analog Power Supply and Other Pins

Using this LSI circuit with voltages beyond the ranges given below can have a bad effect on LSI reliability.

- Range for the setting of analog input voltages
  Keep voltages applied to analog input pins (ANn pins) within the range defined by AVSS ≤ VAN ≤ VREF.
- Power-Supply Pins (AVCC0 – AVSS0, AVCC – AVSS, and VCC – VSS)
  For the various power-supply pins (AVCC0 – AVSS0, AVCC – AVSS, and VCC – VSS), ensure that VCC ≤ AVCC0 = AVCC and AVSS0 = AVSS = VSS hold. If the 10-bit A/D converter is not in use, ensure that VCC = AVCC0 = AVCC and AVSS0 = AVSS = VSS.
- Range for the setting of VREF
  Keep the reference voltage on the VREF pin within the range defined by VREF ≤ AVCC. If the A/D converters are not in use, ensure that VREF = AVCC

29.6.8 Point for Caution Regarding Board Design

As far as possible, separate the analog circuits from the digital circuits in board design. Furthermore, do not allow the wiring runs for a signal of a digital circuit and a signal of an analog circuit to cross or be in each other's vicinity. Inductive coupling causes noise to be generated on the analog signals and has a bad effect on the results of analog conversion. Keep the signal lines for analog input pins (AN0 to AN11), the analog reference power supply pin (VREF), the analog power-supply voltage (AVCC), and analog ground (AVSS) away from digital circuitry. Furthermore, connect the analog ground (AVSS) to the stabilized ground (VSS) on the board at a single point.

29.6.9 Point for Caution Regarding Countermeasures for Noise

To prevent destruction of the circuits for the analog input pins by abnormal voltages such as excessively large surges, connect capacitors as shown in Figure 29.10 between AVCC and AVSS, and between VREF and AVSS; also connect suitable protective circuits to the analog input pins (AN0 to AN11).

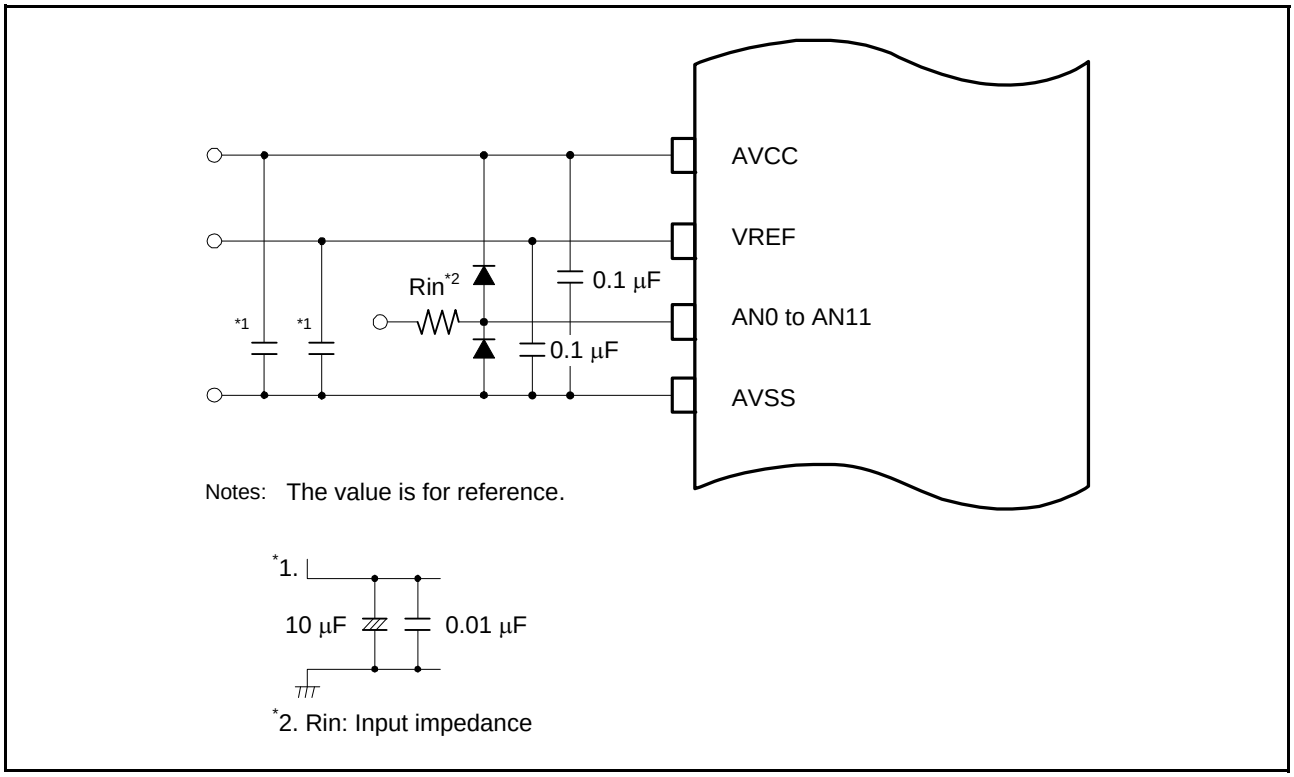


Figure 29.10 Example of a Protective Circuit for Analog Inputs

30. RAM

The RX62T Group has a high-speed static RAM.

30.1 Overview

Table 30.1 lists the specifications of the RAM.

Table 30.1 Specifications of the RAM

Item	Description
RAM capacity	16 Kbytes, 8 Kbytes*1
RAM address	0000 0000h to 0000 3FFFh (16 Kbytes) 0000 0000h to 0000 1FFFh (8 Kbytes)
Access	Single-cycle access is possible for both reading and writing. Enabling or disabling of on-chip RAM is selectable.*2
Power-down function	The module stop function is independently selectable

Note 1. The RAM capacity varies with the product.

Product Name	RAM Capacity	RAM Address
R5F562TAxxxx	16 Kbytes	0000 0000h to 0000 3FFFh
R5F562T7xxxx	8 Kbytes	0000 0000h to 0000 1FFFh
R5F562T6xxxx		

Note 2. Selectable by the RAME bit in SYSCR1. For details on SYSCR1, see section 3.2.4, System Control Register 1 (SYSCR1).

30.2 Operation

30.2.1 Power-Down Function

Power consumption can be reduced by setting the module stop control register C (MSTPCRC) to stop supply of the clock signal to the on-chip RAM.
If the MSTPC0 bit in MSTPCRC is set to 1, supply of the clock signal to RAM is stopped.
The module is placed in the module stop state by stopping supply of the clock signals. The initial value after a reset is for the RAM to be operational.
RAM is not accessible if it is in the module stop state. A transition to the module stop state should not be made while access to RAM is in progress.
For details on the MSTPCRC registers, see section 9, Low Power Consumption.

31. ROM (Flash Memory for Code Storage)

The RX62T Group has two flash-memory modules: a maximum 256-Kbyte ROM (max.) for storing code and a 32-Kbyte (max.) data flash block for storing data.
This section covers the flash memory for code storage. For the data flash, see section 32, Data Flash Memory (Flash Memory for Data Storage).

31.1 Overview

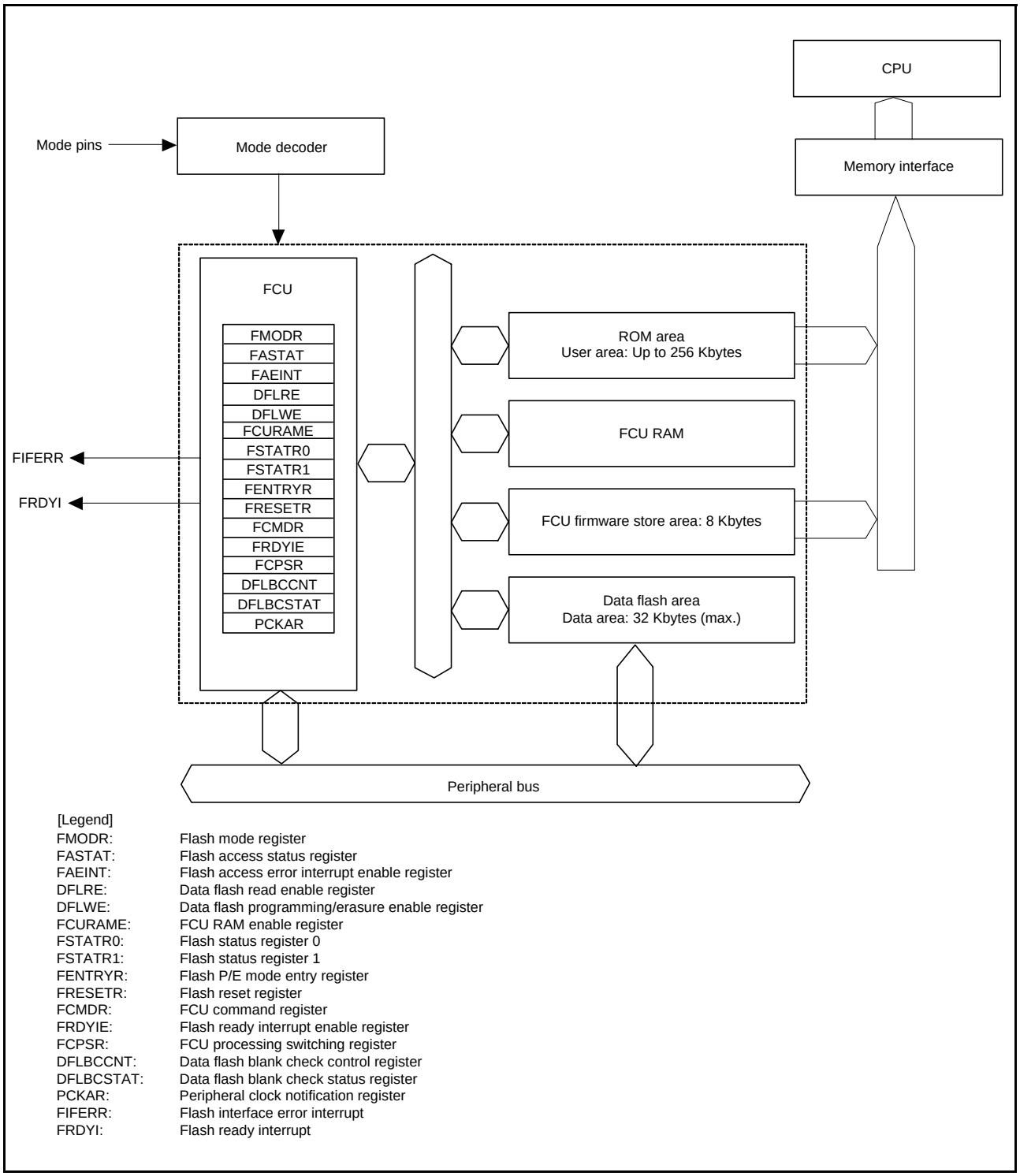
Table 31.1 lists the specifications of the ROM, and Figure 31.1 show a block diagram of the ROM, data-flash memory (data flash), and related modules.

Table 31.1 Specifications of the ROM

Item		Specifications
Memory capacity		User area: 256 Kbytes, 128 Kbytes, or 64 Kbytes*1
High-speed reading		A read operation takes one cycle of ICLK
Programming/erasing method		• The chip incorporates a dedicated sequencer (FCU) for programming of the ROM. • Programming and erasing the ROM are handled by issuing commands to the FCU. • The ROM in the erased state can be read as FFFF FFFFh in 32-bit access.
BGO (background operation)		• The CPU is able to execute program code from areas other than the ROM or data flash while the ROM is being programmed or erased. • Execution of program code from the ROM is possible while the data flash memory is being programmed or erased.
Suspension and resumption		• The CPU is able to execute program code from the ROM during suspension of programming or erasure. • Programming and erasure of the ROM can be restarted (resumed) after suspension.
Units of programming and erasure		• Unit of programming for the user area: 256 bytes • Units of erasure for the user area: 4 Kbytes (8 blocks), 16 Kbytes (when the ROM size is 256 Kbytes: 14 blocks, when the ROM size is 128 Kbytes: 6 blocks, and when the ROM size is 64 Kbytes: 2 blocks)
On-board programming (two types)		Programming in boot mode • The asynchronous serial interface (SCI1) is used. • The transfer rate is adjusted automatically.
		Programming by a routine for ROM programming within the user program • This allows ROM programming without resetting the system.
Off-board programming		A PROM programmer can be used to program the user area.
Protection	Software-controlled protection	The FENTRYR.FENTRY0, FWEPROR.FLWE[1:0], and lock bits can be used to prevent unintentional programming.
	Error protection	Prevention of further programming or erasure after the detection of abnormal operations during programming or erasure
Times for programming and erasure, durability (number of times reprogramming is possible)		See section 33, Electrical Characteristics.

Note 1. Each product has different ROM sizes.

		ROM Addresses	
Product Code	**ROM Size**	**Reading**	**Programming or Erasure**
R5F562TAxxxx	256 Kbytes	FFFC 0000h to FFFF FFFFh	00FC 0000h to 00FF FFFFh
R5F562T7xxxx	128 Kbytes	FFFE 0000h to FFFF FFFFh	00FE 0000h to 00FF FFFFh
R5F562T6xxxx	64 Kbytes	FFFF 0000h to FFFF FFFFh	00FF 0000h to 00FF FFFFh



[Legend]

FMODR:	Flash mode register
FASTAT:	Flash access status register
FAEINT:	Flash access error interrupt enable register
DFLRE:	Data flash read enable register
DFLWE:	Data flash programming/erasure enable register
FCURAME:	FCU RAM enable register
FSTATR0:	Flash status register 0
FSTATR1:	Flash status register 1
FENTRYR:	Flash P/E mode entry register
FRESETR:	Flash reset register
FCMDR:	FCU command register
FRDYIE:	Flash ready interrupt enable register
FCPSR:	FCU processing switching register
DFLBCCNT:	Data flash blank check control register
DFLBCSTAT:	Data flash blank check status register
PCKAR:	Peripheral clock notification register
FIFERR:	Flash interface error interrupt
FRDYI:	Flash ready interrupt

Figure 31.1 Block Diagram of ROM

Input and output pins associated with the ROM are listed in Table 31.2.

Table 31.2 Input and Output Pins Associated with the ROM

Pin Name	I/O	Description
PD5/RxD1	Input	Used in boot mode to receive data via SCI1 (for host communications)
PD3/TxD1	Output	Used in boot mode to transmit data from SCI1 (for host communications)
MD1/MD0	Input	Set the operating mode for the RX62T Group

31.2 Register Descriptions

Table 31.3 lists the registers related to ROM. Although some registers have bits related to data flash, this section deals only with the bits related to ROM. For details on the bits related to the data flash, see section 32.2, Register Descriptions in section 32, Data Flash Memory (Flash Memory for Data Storage).
The registers related to the ROM are initialized by a reset.

Table 31.3 Registers Related to ROM

Register Name	Symbol	Value after Reset	Address	Access Size
Flash mode register	FMODR	00h	007F C402h	8
Flash access status register	FASTAT	00h	007F C410h	8
Flash access error interrupt enable register	FAEINT	9Bh	007F C411h	8
Flash ready interrupt enable register	FRDYIE	00h	007F C412h	8
FCU RAM enable register	FCURAME	0000h	007F C454h	16
Flash status register 0	FSTATR0	80h	007F FFB0h	8
Flash status register 1	FSTATR1	0xh	007F FFB1h	8
Flash P/E mode entry register	FENTRYR	0000h	007F FFB2h	16
Flash protection register	FPROTR	0000h	007F FFB4h	16
Flash reset register	FRESETR	0000h	007F FFB6h	16
FCU command register	FCMDR	FFFFh	007F FFBAh	16
FCU processing switching register	FCPSR	0000h	007F FFC8h	16
Flash P/E status register	FPESTAT	0000h	007F FFCCh	16
Peripheral clock notification register	PCKAR	0000h	007F FFE8h	16
Flash write erase protection register	FWEPROR	02h	0008 C289h	8

31.2.1 Flash Mode Register (FMODR)

Address: 007F C402h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	FRDMD	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b3 to b0	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b4	FRDMD	FCU Read Mode Select	0: Memory Area Read Method Memory area read mode is set to read a lock bit of ROM in ROM lock bit read mode. 1: Register Read Method Register read mode is set to read a lock bit of ROM using the lock bit read 2 command.	R/W
b7 to b5	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

FMODR is a register to specify the method for the reading of lock bits.
When on-chip ROM is disabled, the data read from FMODR is 00h and writing is disabled.
FMODR is initialized by a reset.

FRDMD Bit (FCU Read Mode Select)

This bit is used to specify the method for the reading of lock bits.
If the blank checking command for the data flash is to be used, this bit has to be set for the register read mode (see section 32, Data Flash Memory (Flash Memory for Data Storage)).

31.2.2 Flash Access Status Register (FASTAT)

Address: 007F C410h

	b7	b6	b5	b4	b3	b2	b1	b0
	ROMAE	—	—	CMDLK	DFLAE	—	DFLRPE	DFLWPE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	DFLWPE	Data Flash Programming/Erasure Protection Violation	See section 32, Data Flash Memory (Flash Memory for Data Storage).	R/(W)*1
b1	DFLRPE	Data Flash Read Protection Violation	See section 32, Data Flash Memory (Flash Memory for Data Storage).	R/(W)*1
b2	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b3	DFLAE	Data Flash Access Violation	See section 32, Data Flash Memory (Flash Memory for Data Storage).	R/(W)*1
b4	CMDLK	FCU Command Lock	0: FCU is not in the command-locked state 1: FCU is in the command-locked state	R
b6, b5	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7	ROMAE	ROM Access Violation	0: No ROM access error 1: ROM access error	R/(W)*1

Note 1. Only 0 can be written after reading 1 to clear the flag.

FASTAT is a register to check if the access to the ROM/data flash is allowed.
When on-chip ROM is disabled, the data read from FASTAT is 00h and writing is disabled. When one of the bits in FASTAT is set to 1, the FCU is placed in the command-locked state (see section 31.8.2, Error Protection). To clear the command-locked state, a status register clearing command must be issued to the FCU after setting FASTAT to 10h.
FASTAT is initialized by a reset.

CMDLK Bit (FCU Command Lock)

This bit indicates that the FCU is in the command-locked state (see section 31.8.2, Error Protection).
[Setting condition]

- After the FCU detects an error and enters the command-locked state

[Clearing condition]

- After the FCU processes a status register clearing command under conditions where FASTAT is set to 10h

ROMAE Bit (ROM Access Violation)

This bit indicates whether a ROM access violation occurred.
When the ROMAE bit is set to 1, the ILGLERR bit in FSTATR0 is set to 1, placing the FCU in the command-locked state.
[Setting conditions]

- A read command is issued for ROM programming/erasure addresses 00FC 0000h to 00FF FFFFh when the FCU is in ROM P/E normal mode and the FENTRYR.FENTRY0 bit is set to 1.
- A command is issued for ROM programming/erasure addresses 00FC 0000h to 00FF FFFFh when the FENTRY0 bit is set to 0.
- A read command is issued for ROM read addresses FFFC 0000h to FFFF FFFFh when FENTRYR is set to other than 0000h.

[Clearing condition]

- When 0 is written after reading 1

31.2.3 Flash Access Error Interrupt Enable Register (FAEINT)

Address: 007F C411h

	b7	b6	b5	b4	b3	b2	b1	b0
	ROMAEIE	—	—	CMDLKIE	DFLAEIE	—	DFLRPEIE	DFLWPEIE
Value after reset:	1	0	0	1	1	0	1	1

Bit	Symbol	Bit Name	Description	R/W
b0	DFLWPEIE	Data Flash Programming/Erasure Protection Violation Interrupt Enable	See section 32, Data Flash Memory (Flash Memory for Data Storage).	R/W
b1	DFLRPEIE	Data Flash Read Protection Violation Interrupt Enable	See section 32, Data Flash Memory (Flash Memory for Data Storage).	R/W
b2	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b3	DFLAEIE	Data Flash Access Violation Interrupt Enable	See section 32, Data Flash Memory (Flash Memory for Data Storage).	R/W
b4	CMDLKIE	FCU Command Lock Interrupt Enable	0: FIFERR interrupt requests disabled when the CMDLK bit in FASTAT is set to 1 1: FIFERR interrupt requests enabled when the CMDLK bit in FASTAT is set to 1	R/W
b6, b5	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7	ROMAEIE	ROM Access Violation Interrupt Enable	0: FIFERR interrupt requests disabled when the ROMAE bit in FASTAT is set to 1 1: FIFERR interrupt requests enabled when the ROMAE bit in FASTAT is set to 1	R/W

FAEINT is a register to enable and disable the flash interface error interrupt (FIFERR).
When on-chip ROM is disabled, the data read from FAEINT is 00h and writing is disabled.
FAEINT is initialized by a reset.

CMDLKIE Bit (FCU Command Lock Interrupt Enable)

This bit is used to enable or disable FIFERR interrupt requests when an FCU command lock occurs and the CMDLK bit in FASTAT is set to 1.

ROMAEIE Bit (ROM Access Violation Interrupt Enable)

This bit is used to enable or disable FIFERR interrupt requests when a ROM access violation occurs and the ROMAE bit in FASTAT is set to 1.

31.2.4 FCU RAM Enable Register (FCURAME)

Address: 007F C454h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	KEY[7:0]								—	—	—	—	—	—	—	FCRME
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	FCRME	FCU RAM Enable	0: Access to the FCU RAM disabled 1: Access to the FCU RAM enabled	R/W
b7 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b15 to b8	KEY[7:0]	Key Code	This bit is used to enable or disable rewriting of the FCRME bit.	R/(W)*1

Note 1. Write data is not retained.

FCURAME is a register to enable and disable an access to the FCU RAM area.
Only specific values written to the upper byte in word access are valid. Data written to the upper byte is not retained.
When on-chip ROM is disabled, the data read from FCURAME is 00h and writing is disabled.
FCURAME is initialized by a reset.

FCRME Bit (FCU RAM Enable)

This bit is used to enable and disable an access to the FCU RAM.
Data written to the FCRME bit is valid only when it is written in word access and the KEY[7:0] bits are C4h. When programming data to the FCU RAM, set FENTRYR to 0000h and stop the FCU.

KEY[7:0] Bits (Key Code)

These bits are used to enable or disable rewriting of the FCRME bit.
Data written to the KEY[7:0] bits is not retained.

31.2.5 Flash Status Register 0 (FSTATR0)

Address: 007F FFB0h

	b7	b6	b5	b4	b3	b2	b1	b0
	FRDY	ILGLERR	ERSERR	PRGERR	SUSRDY	—	ERSSPD	PRGSPD
Value after reset:	1	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	PRGSPD	Programming Suspend Status	0: Other than the status described below 1: During programming suspend processing or programming suspended	R
b1	ERSSPD	Erasure Suspend Status	0: Other than the status described below 1: When erasure suspend processing or erasure suspended	R
b2	—	Reserved	This bit is always read as 0. Writing to this bit has no effect.	R
b3	SUSRDY	Suspend Ready	0: P/E suspend commands cannot be received 1: P/E suspend commands can be received	R
b4	PRGERR	Programming Error	0: Programming terminates normally 1: An error occurs during programming	R
b5	ERSERR	Erasure Error	0: Erasure terminates normally 1: An error occurs during erasure	R
b6	ILGLERR	Illegal Command Error	0: FCU detects no illegal command or ROM/data flash access 1: FCU detects an illegal command or ROM/data flash access	R
b7	FRDY	Flash Ready	0: During programming/erasure, During suspending programming/erasure, During the lock bit read 2 command processing, During the peripheral clock notification command processing During the blank check processing of data flash (See section 32, Data Flash Memory (Flash Memory for Data Storage)). 1: Processing described above is not performed	R

FSTATR0 is a register to check the FCU status.
When on-chip ROM is disabled, the data read from FSTATR0 is 00h.
FSTATR0 is initialized by a reset, or when the FRESET bit in FRESETR is set to 1.

PRGSPD Bit (Programming Suspend Status)

This bit is used to indicate that the FCU enters the programming suspend processing state or programming suspended state (see section 31.7, Suspending Operation).
[Setting condition]

- The FCU has initiated a write suspend command.

[Clearing condition]

- The FCU has accepted a resume command.

ERSSPD Bit (Erasure Suspend Status)

This bit is used to indicate that the FCU enters the erasure suspend processing state or erasure suspended state (see section 31.7, Suspending Operation).
[Setting condition]

- The FCU has initiated an erasure suspend command.

[Clearing condition]

- The FCU has accepted a resume command.

SUSRDY Bit (Suspend Ready Status)

This bit is used to indicate whether the FCU can receive a P/E suspend command.
[Setting condition]

- After starting programming/erasure process, the FCU enters a state in which P/E suspend commands can be received.

[Clearing conditions]

- The FCU has accepted a P/E suspend command.
- During programming/erasure process, the FCU enters the command-locked state.

PRGERR Bit (Programming Error)

This bit is used to indicate the result of the ROM/data flash programming process by the FCU.
When the PRGERR bit is set to 1, the FCU is placed in the command-locked state (see section 31.8.2, Error Protection).
[Setting condition]

- An error occurs during programming.
- A programming command is issued to areas protected by a lock bit.

[Clearing condition]

- After the FCU processes a status register clearing command

ERSERR Bit (Erasure Error)

This bit is used to indicate the result of the ROM/data flash erasure process by the FCU.
When the ERSERR bit is set to 1, the FCU is placed in the command-locked state (see section 31.8.2, Error Protection).
[Setting condition]

- An error occurs during erasure.
- A block erase command is issued to areas protected by a lock bit.

[Clearing condition]

- After the FCU processes a status register clearing command

ILGLERR Bit (Illegal Command Error)

This bit is used to indicate that the FCU detects any illegal command or ROM/data flash access.
When the ILGLERR bit is set to 1, the FCU is placed in the command-locked state (see section 31.8.2, Error Protection).
[Setting conditions]

- The FCU detects an illegal command.
- The FCU detects an illegal ROM/data flash access
  (one of the ROMAE, DFLAE, DFLRPE, and DFLWPE bits in FASTAT is 1).
- The setting of FENTRYR is invalid.

[Clearing condition]

- After the FCU processes a status register clearing command under conditions where FASTAT is set to 10h

FRDY Bit (Flash Ready)

This bit is used to check the processing status of the FCU.

31.2.6 Flash Status Register 1 (FSTATR1)

Address: 007F FFB1h

	b7	b6	b5	b4	b3	b2	b1	b0
	FCUERR	—	—	FLOCKST	—	—	—	—
Value after reset:	0	0	0	0	0	0	x	x

x: Undefined

Bit	Symbol	Bit Name	Description	R/W
b1, b0	—	Reserved	The read value is undefined. Writing to these bits has no effect.	R
b3, b2	—	Reserved	These bits are always read as 0. Writing to these bits has no effect.	R
b4	FLOCKST	Lock Bit Status	0: Protected 1: Not protected	R
b6, b5	—	Reserved	These bits are always read as 0. Writing to these bits has no effect.	R
b7	FCUERR	FCU Error	0: No error occurs in the FCU processing 1: An error occurs in the FCU processing	R

FSTATR1 is a register to check the FCU status.
When on-chip ROM is disabled, the data read from FSTATR1 is 00h.
FSTATR1 is initialized by a reset, or when the FRESET bit in FRESETR is set to 1.

FLOCKST Bit (Lock Bit Status)

This bit is to reflect the read data of a lock bit when using the lock bit read 2 command.
When the FRDY bit in FSTATR0 is set to 1 after a lock bit read 2 command is issued, valid data is stored in the FLOCKST bit. The value of the FLOCKST bit is retained until the completion of the next lock bit read 2 command.

FCUERR Bit (FCU Error)

This bit is used to indicate that an error occurs in the FCU internal processing.
When the FCUERR bit is set to 1, set the FRESET bit in FRESETR to 1 to initialize the FCU. Additionally, recopy the FCU firmware from the FCU firmware area to the FCU RAM area.

31.2.7 Flash Ready Interrupt Enable Register (FRDYIE)

Address: 007F C412h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	FRDYIE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	FRDYIE	Flash Ready Interrupt Enable	0: FRDYI interrupt requests disabled 1: FRDYI interrupt requests enabled	R/W
b7 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

FRDYIE is a register to enable and disable the flash ready interrupt (FRDYI) output.
When on-chip ROM is disabled, the data read from FRDYIE is 00h and writing is disabled.
FRDYIE is initialized by a reset.

FRDYIE Bit (Flash Ready Interrupt Enable)

This bit is to enable/disable a FRDYI interrupt request when programming/erasure is completed.
If the FRDYIE bit is set to 1, a flash ready interrupt request (FRDYI) is generated when execution of the FCU command has completed (FSTATR0.FRDY bit changes from 0 to 1).

31.2.8 Flash P/E Mode Entry Register (FENTRYR)

Address: 007F FFB2h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	FEKEY[7:0]								FENTRYD	—	—	—	—	—	—	FENTRY0
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	FENTRY0	ROM P/E Mode Entry 0	0: ROM is in ROM reading mode 1: ROM is in ROM P/E mode.	R/W
b6 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7	FENTRYD	E2 Data Flash P/E Mode Entry	See section 32, Data Flash Memory (Flash Memory for Data Storage).	R/W
b15 to b8	FEKEY[7:0]	Key Code	These bits enable or disable rewriting of the FENTRYD and FENTRY0 bits.	R/(W) *1

Note 1. Write data is not retained.

FENTRYR is a register to place the ROM/data flash in P/E mode.
To place the ROM/data flash in P/E mode so that the FCU can accept commands, either the FENTRYD or FENTRY0 bit must be set to 1. Note that if both bits are set to 1, the ILGLERR bit in FSTATR0 is set and the FCU enters the command-locked state.
Only specific values written to the upper byte in word access are valid. Any other writing causes the register to be initialized. Data written to the upper byte is not retained.
When on-chip ROM is disabled, the data read from FENTRYR is 0000h and writing is disabled.
FENTRYR is initialized by a reset, or when the FRESET bit in FRESETR is set to 1.

FENTRY0 Bit (ROM P/E Mode Entry 0)

This bit is used to place the ROM in P/E mode.
[Writing-enable conditions (when all of the following conditions are met)]

- On-chip ROM is enabled.
- The FRDY bit in FSTATR0 is set to 1.
- AAh is written to the FEKEY[7:0] bits in word access.

[Setting condition]

- When the writing-enable conditions are met, FENTRYR is set to 0000h, and 1 is written to the FENTRY0 bit

[Clearing conditions]

- Data is written in byte access.
- Data is written in word access when the FEKEY[7:0] bits are other than AAh.
- When the writing-enable conditions are met, 0 is written to the FENTRY0 bit.
- When the writing-enable conditions are met and FENTRYR is other than 0000h, data is written to FENTRYR.

FEKEY[7:0] Bits (Key Code)

These bits enable or disable rewriting of the FENTRYD and FENTRY0 bits.
Data written to the FEKEY[7:0] bits is not retained.

31.2.9 Flash Protection Register (FPROTR)

Address: 007F FFB4h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	FPKEY[7:0]								—	—	—	—	—	—	—	FPROTCN
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	FPROTCN	Lock Bit Protection Cancel	0: Protection with a lock bit enabled 1: Protection with a lock bit disabled	R/W
b7 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b15 to b8	FPKEY[7:0]	Key Code	These bits are used to enable or disable rewriting of the FPROTCN bit.	R/(W) *1

Note 1. Write data is not retained.

FPROTR is a register used to enable/disable the programming/erasure protection function with a lock bit.
Only specific values written to the upper byte in word access are valid. Any other writing causes the register to be initialized. Data written to the upper byte is not retained.
When on-chip ROM is disabled, the data read from FPROTR is 0000h and writing is disabled.
FPROTR is initialized by a reset, or when the FRESET bit in FRESETR is set to 1.

FPROTCN Bit (Lock Bit Protection Cancel)

This bit is used to enable/disable the programming/erasure protection with a lock bit.
[Setting condition]

- The FPKEY[7:0] bits are set to 55h, and the FPROTCN bit is set to 1 in word access when the value of FENTRYR is other than 0000h.

[Clearing conditions]

- Data is written in byte access.
- Data is written in word access when the FPKEY[7:0] bits are other than 55h.
- The FPKEY[7:0] bits are set to 55h, and the FPROTCN bit is set to 0 in word access.
- The value of FENTRYR is 0000h.

FPKEY[7:0] Bits (Key Code)

These bits are used to enable or disable rewriting of the FPROTCN bit.
Data written to the FPKEY[7:0] bits is not retained.

31.2.10 Flash Reset Register (FRESETR)

Address: 007F FFB6h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	FRKEY[7:0]								—	—	—	—	—	—	—	FRESET
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	FRESET	Flash Reset	0: FCU is not reset 1: FCU is reset	R/W
b7 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b15 to b8	FRKEY[7:0]	Key Code	These bits are used to enable or disable rewriting of the FRESET bit.	R/(W) *1

Note 1. Write data is not retained.

FRESETR is a register to initialize the FCU.
Only specific values written to the upper byte in word access are valid. Data written to the upper byte is not retained.
When on-chip ROM is disabled, the data read from FRESETR is 0000h and writing is disabled.
FRESETR is initialized by a reset.

FRESET Bit (Flash Reset)

When the FRESET bit is set to 1, programming/erasure operations for the ROM/data flash are forcibly terminated, and the FCU is initialized.
High voltage is applied to the memory of the ROM/data flash during programming/erasure. To ensure time required for dropping the voltage applied to the memory, keep the FRESET bit set to 1 for tRESW2 (see section 33, Electrical Characteristics) when initializing the FCU. While the FRESET bit is kept 1, prohibit the ROM/data flash from being read. Additionally, when the FRESET bit is set to 1, the FCU commands cannot be used because FENTRYR is initialized.
Writing of the FRESET bit is enabled only in word access and when the FRKEY[7:0] bits are CCh.

FRKEY[7:0] Bits (Key Code)

These bits are used to enable or disable rewriting of the FRESET bit.
Data written to the FRKEY[7:0] bits is not retained.

31.2.11 FCU Command Register (FCMDR)

Address: 007F FFBAh

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	CMDR[7:0]								PCMDR[7:0]							
Value after reset:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Bit	Symbol	Bit Name	Description	R/W
b7 to b0	PCMDR[7:0]	Precommand	Store the command immediately before the last command received by the FCU.	R
b15 to b8	CMDR[7:0]	Command	Store the last command received by the FCU.	R

FCMDR is a register to store commands received by the FCU.
When on-chip ROM is disabled, the data read from FCMDR is 0000h and writing is disabled.
FCMDR is initialized by a reset, or when the FRESET bit in FRESETR is set to 1.
Table 31.4 lists the states of FCMDR after receiving each command. For details on the blank check processing, see section 32.6, Programming and Erasing the Data Flash Memory in section 32, Data Flash Memory (Flash Memory for Data Storage).

Table 31.4 States of FCMDR after Receiving Each Command

Command	CMDR	PCMDR
P/E Normal mode transition	FFh	Previous command
Status read mode transition	70h	Previous command
Lock bit read mode transition (lock bit read 1)	71h	Previous command
Peripheral clock notification command	E9h	Previous command
Programming	E8h	Previous command
Block erase	D0h	20h
P/E suspend	B0h	Previous command
P/E resume	D0h	Previous command
Status register clearing	50h	Previous command
Lock bit read 2/blank check	D0h	71h
Lock bit programming	D0h	77h

31.2.12 FCU Processing Switching Register (FCPSR)

Address: 007F FFC8h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	ESUSPMD
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	ESUSPMD	Erasure Suspend Mode	0: Suspension priority mode 1: Erasure priority mode	R/W
b15 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

FCPSR is a register to select the method of suspending the FCU erasure processing.
When on-chip ROM is disabled, the data read from FCPSR is 0000h and writing is disabled.
FCPSR is initialized by a reset, or when the FRESET bit in FRESETR is set to 1.

ESUSPMD Bit (Erasure Suspend Mode)

This bit is to select the erasure suspend mode for when a P/E suspend command is issued while the FCU executes the erasure processing for the ROM/data flash (see section 31.7, Suspending Operation).

31.2.13 Flash P/E Status Register (FPESTAT)

Address: 007F FFCCh

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	PEERRST[7:0]							
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b7 to b0	PEERRST[7:0]	P/E Error Status	00h: No programming error 01h: Programming error against areas protected by a lock bit 02h: Programming error due to sources other than the lock bit protection 11h: Erasure error against areas protected by a lock bit 12h: Erasure error due to sources other than the lock bit protection (Values other than above are reserved)	R
b15 to b8	—	Reserved	These bits are always read as 0 and cannot be modified.	R

FPESTAT is a register to indicate the result of the programming/erasure processing for the ROM/data flash.
When on-chip ROM is disabled, the data read from FPESTAT is 0000h and writing is disabled.
FPESTAT is initialized by a reset, or when the FRESET bit in FRESETR is set to 1.

PEERRST[7:0] Bits (P/E Error Status)

These bits are used to indicate the reason of an error that occurs during the programming/erasure processing for the ROM/data flash.
The value of the PEERRST[7:0] bits is valid only when the ERSERR bit or PRGERR bit in FSTATR0 is 1. The value of the reason of the past error is retained in the PEERRST[7:0] bits when the ERSERR bit and PRGERR bit is 0.

31.2.14 Peripheral Clock Notification Register (PCKAR)

Address: 007F FFE8h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	PCKA[7:0]							
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b7 to b0	PCKA[7:0]	Peripheral Clock Notification	These bits are used to set the flashIF clock (FCLK) at the programming/erasure for the ROM/E2 data flash.	R/W
b15 to b8	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

PCKAR is a register to notify the sequencer of the frequency setting data of the peripheral clock (PCLK) at the programming/erasure for the ROM/data flash. This setting is used to control programming and erasure times.
When on-chip ROM is disabled, the data read from PCKAR is 0000h and writing is disabled.
PCKAR is initialized by a reset, or when the FRESET bit in FRESETR is set to 1.

PCKA[7:0] Bits (Peripheral Clock Notification)

These bits are used to set the peripheral clock (PCLK) at the programming/erasure for the ROM/data flash.
Set the PCKA[7:0] bits to the PCLK frequency and issue a peripheral clock notification command before programming/erasure. Do not change the frequency during the programming/erasure processing for the ROM/data flash.
Calculate the setting value as follows:

- Convert an operating frequency represented in MHz units to binary and write it to the PCKA[7:0] bits.
- For example, when the operating frequency of the peripheral clock is 35.9 MHz, the setting value is calculated as follows:
- Round up 35.9
- Convert 36 to binary and set the upper bits and lower bits of the PCKA[7:0] bits to 00h and 24h (0010 0100b).

Note 1. When the PCKA[7:0] bits are set to values outside the range from 8 to 50 MHz, do not issue a programming command to the ROM/data flash.
Note 2. When the PCKA[7:0] bits are set to a frequency that is different from the actual frequency, the data of the ROM/data flash may crash.
Note 3. Please note that programming time depends on the frequency to some extent even if the PCKA[7:0] bits are used.

31.2.15 Flash Write Erase Protection Register (FWEPROR)

Address: 0008 C289h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	FLWE[1:0]	
Value after reset:	0	0	0	0	0	0	1	0

Bit	Symbol	Bit Name	Description	R/W
b1, b0	FLWE[1:0]	Flash Programming/ Erasure	b1 b0 0 0: Flash programming/erasure disabled. 0 1: Flash programming/erasure enabled. 1 0: Flash programming/erasure disabled. (initial value) 1 1: Flash programming/erasure disabled.	R/W
b7 to b2	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

FWEPROR is a readable/writable register to protect the execution of the flash write/erase with software.
FWEPROR is initialized in software standby mode or deep software standby.

FLWE[1:0] Bits (Flash Write Erase)

These bits protect the execution of the flash write/erase with software.

31.3 Configuration of Memory Areas for the ROM

The ROM of products in the RX62T Group is configured of a maximum 256-Kbyte user area. The address range occupied by this area is shown in Figure 31.2.
Note that for the user area, the address range for reading differs from the address range for programming and erasure.

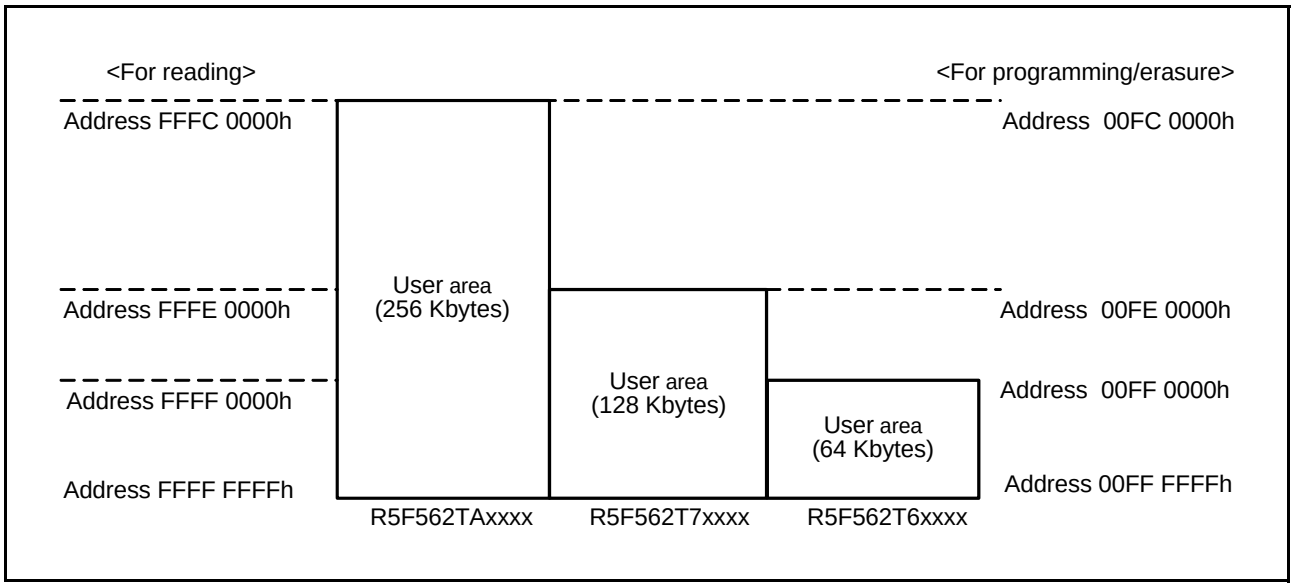


Figure 31.2 Memory Area Configuration of ROM

31.4 Block Configuration

The configuration of erasure blocks for the user area is shown in Figure 31.3. As units of erasure, the user area is divided into 8 blocks of 4 Kbytes each and 14 blocks of 16 Kbytes each. For programming, the user area consists of the 256-byte units starting from 00h as the lower-order byte of the address.

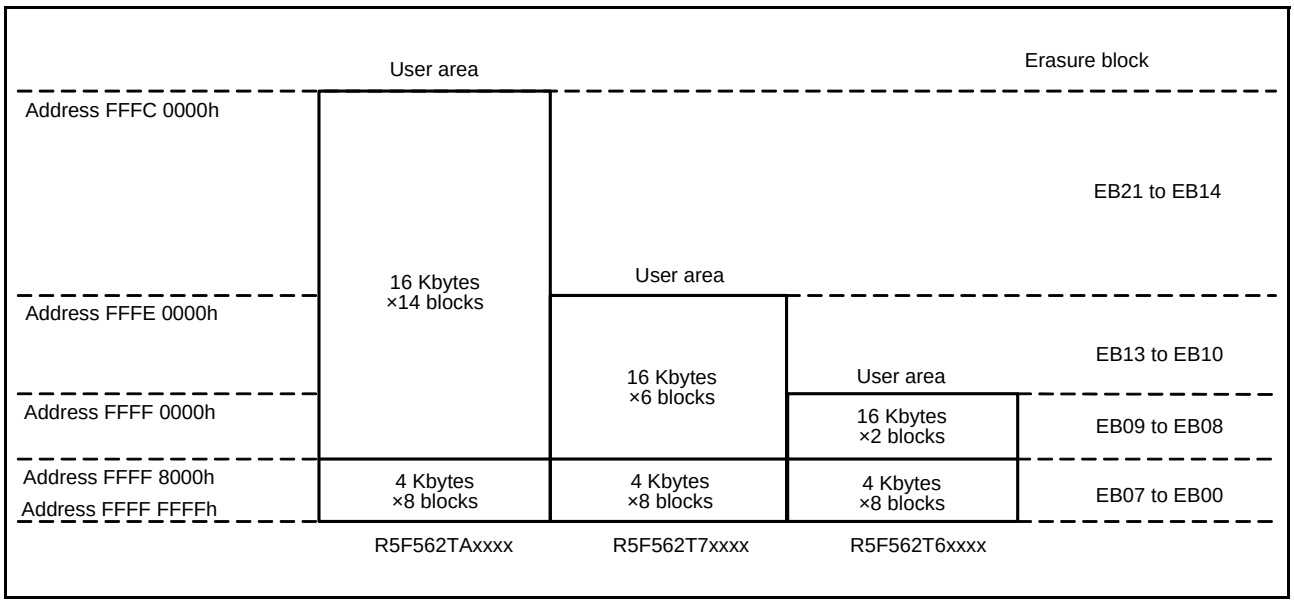


Figure 31.3 Configuration of Erasure Blocks for the User Area

31.5 Operating Modes Associated with the ROM

Figure 31.4 is a diagram of the operating-mode transitions for the RX62T Group.
On release from the reset state, transitions are in accord with the levels on the MD0 and MD1 pins, as shown in Figure 31.4.
For more information on the connections between the settings of the levels on the MD0 and MD1 pins and the operating mode for the RX62T Group, refer to section 3, Operating Modes.

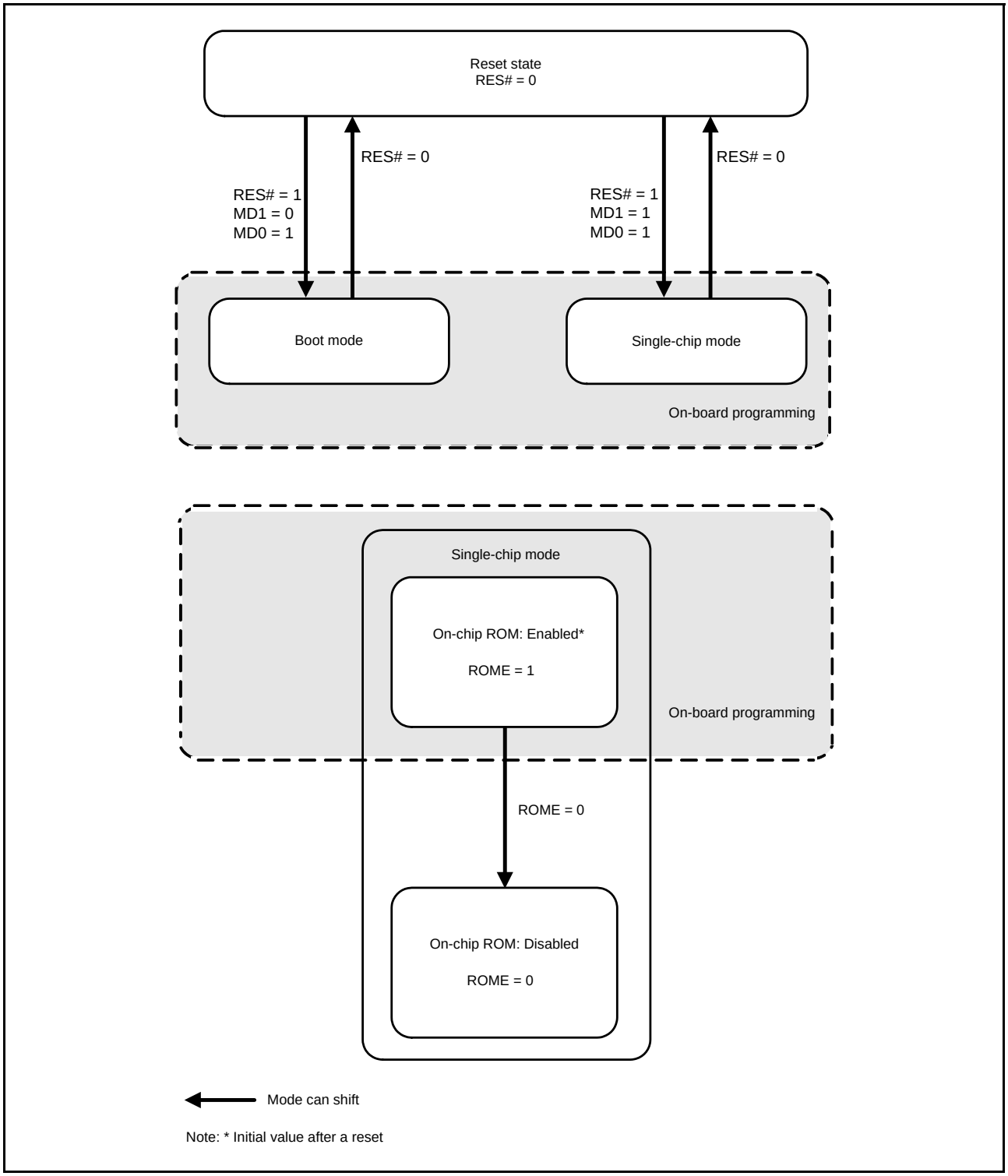


Figure 31.4 Transitions between Operating Modes in Terms of the ROM

Reading, programming, and erasing of the ROM in an on-board device can proceed if the device is in boot or single-chip mode (with on-chip ROM enabled), or in on-chip-ROM-enabled expansion mode.
Which areas are programmable and erasable, the area from which booting up proceeds after a reset, etc., differs with the mode. The differences between modes are indicated in Table 31.5.

Table 31.5 Differences between Modes

Item	Boot Mode	Single-Chip Mode (with On-chip ROM Enabled)
Environment for programming and erasure	On-board programming	On-board programming
Programmable and erasable area	User area	User area
Division into erasure blocks	Possible*1	Possible
Target area for booting after a reset	Area containing the embedded program*2	User area

Note 1. The entire ROM may be erased at the time of booting up. Specified blocks can subsequently be erased. For details, refer to section 31.9.2, ID Code Protection.
Note 2. Not available to users.

- In boot mode, a host is able to program or read out the user area or data area via an SCI.
- In boot mode, on-chip RAM is employed for the embedded program for use in boot mode. For this reason, preserving the contents of on-chip RAM is not possible in this case.

31.6 Programming and Erasing the ROM

The ROM is programmed and erased by issuing commands to a dedicated sequencer (FCU) for programming and erasure. The FCU has five modes. For programming and erasure, the mode is changed and then commands for programming and erasure are issued.
The mode transitions required to program or erase the ROM and the system of commands are described below. The descriptions apply in common to boot and single-chip mode (with on-chip ROM enabled).

31.6.1 FCU Modes

The FCU has five modes or sets of modes. Transitions between modes are caused by modifying FENTRYR or issuing FCU commands. Figure 31.5 is a diagram of the FCU mode transitions.

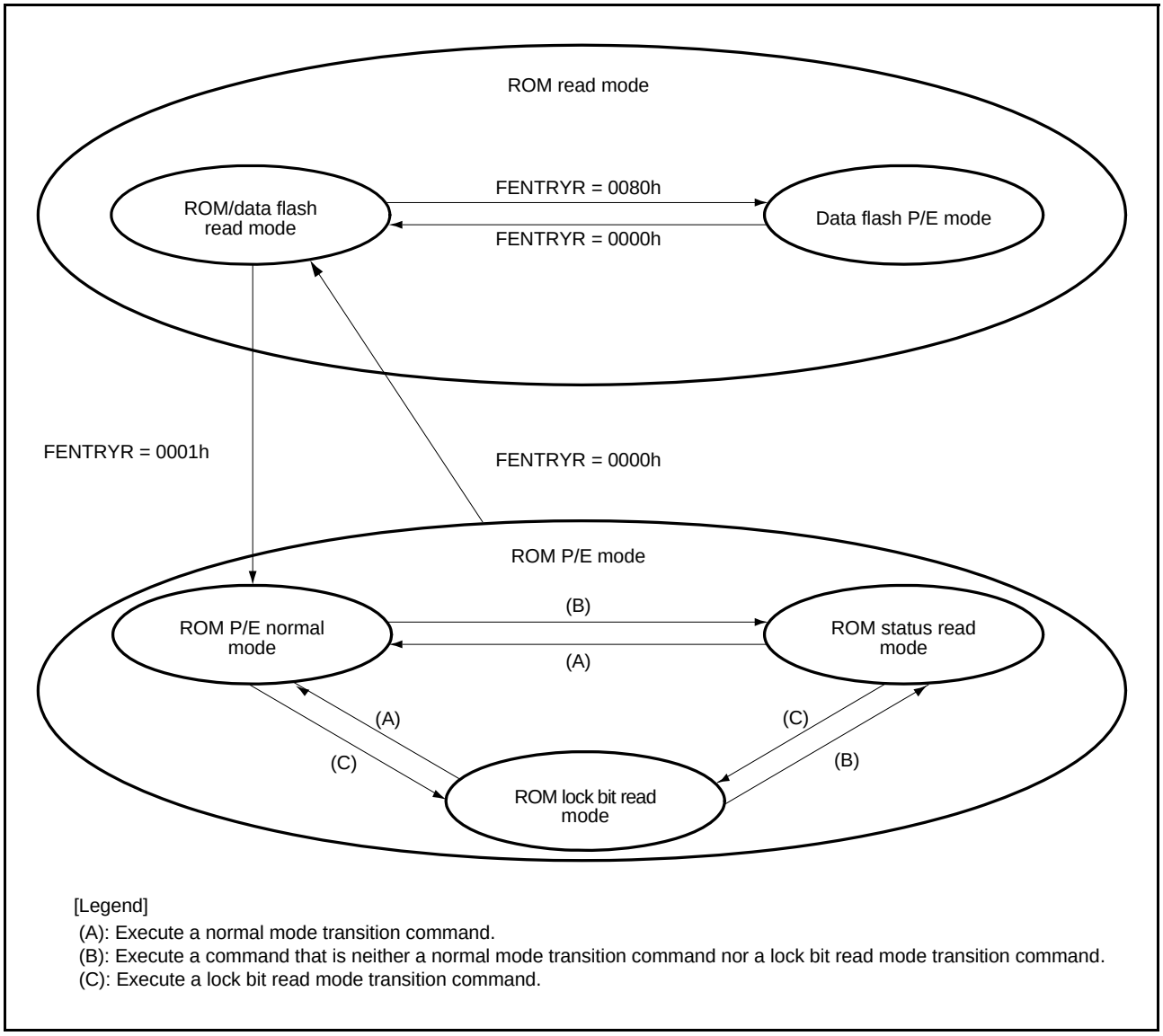


Figure 31.5 Mode Transitions of the FCU (Associated with the ROM)

31.6.1.1 ROM Read Modes

The ROM read modes are for high-speed reading of the ROM. Access to an address for reading can be accomplished in one cycle of ICLK.
ROM/data-flash read mode and data-flash P/E mode are the two kinds of ROM reading mode.

(1) ROM/Data Flash Read Mode

This mode is for reading the ROM and data-flash memory. The FCU does not accept commands.
The FCU enters this mode when the FENTRY0 bit in FENTRYR is set to 0, and the FENTRYD bit in FENTRYR is set to 0.

(2) Data Flash P/E Modes

These modes are for programming and erasure of the data-flash memory. High-speed reading of the ROM is also possible. Although the FCU accepts FCU commands related to the data-flash memory in this mode, it does not accept FCU commands related to the ROM. The FCU enters these modes when the FENTRY0 bit in FENTRYR is set to 0, or the FENTRYD bit in FENTRYR is set to 1.
For details on the data flash P/E modes, see section 32.6.1, FCU Modes, in section 32, Data Flash Memory (Flash Memory for Data Storage).

31.6.1.2 ROM P/E Modes

The ROM P/E modes are for programming and erasure of the ROM. High-speed reading of the ROM is not possible in these modes. Read access to an address within the range for reading causes a ROM-access violation, and the FCU enters the command-locked state (see section 31.8.2, Error Protection).
ROM P/E normal mode, ROM status read mode, and ROM lock-bit read mode are the three ROM P/E modes.

(1) ROM P/E Normal Mode

The transition to ROM P/E normal mode is the first transition in the process of programming or erasing the ROM. The FCU enters this mode when the FENTRYD bit in FENTRYR is set to 0, and the FENTRY0 bit in FENTRYR is set to 1 in ROM read mode, or when the normal mode transition command is received in ROM P/E modes. Table 31.8 lists the acceptable commands in this mode.
Read access to an address within the range for programming and erasure while the FENTRY0 bit in FENTRYR is set to 1 causes a ROM-access violation, and the FCU enters the command-locked state (see section 31.8.2, Error Protection).

(2) ROM Status Read Mode

The ROM status read mode is for reading information on the state of the ROM. The FCU enters this mode when a command other than the normal mode transition and lock bit read mode transition command is received in ROM P/E modes.
ROM status read mode encompasses the states where the FRDY bit in FSTATR0 is 0 and the command-locked state after an error has occurred. Table 31.8 lists the acceptable commands in this mode.
Read access to an address within the range for programming and erasure while the FENTRY0 bit in FENTRYR is 1 will actually read out the value of FSTATR0.

(3) ROM Lock-Bit Read Mode

The ROM lock-bit read mode is for reading the values of the lock bits of the ROM. The FCU enters this mode when a lock-bit read mode transition command is received in ROM P/E modes. Table 31.8 lists the acceptable commands in this mode.
In read access to an address within the range for programming and erasure while the FENTRY0 bit in FENTRYR is 1, all bits of the value read out have the value of the lock bit of the erasure block that includes the accessed address.

31.6.2 FCU Commands

FCU commands consist of commands for mode transitions of the FCU and commands for programming and erasure. Table 31.6 lists the FCU commands for use with the ROM.

Table 31.6 FCU Commands for Use with the ROM

Command	Description
P/E normal mode transition	Changes the mode to normal mode (see section 31.6.3, Connections between FCU Modes and Commands)
Status read mode transition	Changes the mode to status read mode (see section 31.6.3, Connections between FCU Modes and Commands)
Lock bit read mode transition (lock bit read 1)	Changes the mode to lock bit read mode (see section 31.6.3, Connections between FCU Modes and Commands)
Peripheral clock notification	Sets the frequency of the peripheral clock
Programming	ROM programming (in 256-byte units)
Block erasure	ROM erasure (in block units, with the lock bit being erased simultaneously)
P/E suspension	Suspends programming/erasure
P/E resumption	Resumes programming/erasure
Status register clearing	Clears the ILGLERR, ERSERR and PRGERR bits in FSTATR0 and releases the FCU from the command locked state
Lock bit read 2/blank checking	Reads the lock bit of a specified erasure block (the value of the lock bit is reflected in the FLOCKST bit of FSTATR1)/blank checking of the data-flash memory
Lock bit programming	Programs the lock bit of a specified erasure block

The lock bit read 2 command is also used as the blank-checking command for the data-flash memory. That is, when a lock bit read 2 command is issued for the data flash, blank checking is executed for the data-flash memory (see section 32, Data Flash Memory (Flash Memory for Data Storage)).
Commands for the FCU are issued by write access to addresses within the range for programming and erasure. Table 31.7 shows the formats of the FCU commands. Write access as listed in Table 31.7 and in accord with certain conditions causes the FCU to execute processing for the corresponding command. For details on the conditions for the acceptance of the individual FCU commands, see section 31.6.3, Connections between FCU Modes and Commands. For how to use the FCU commands, see section 31.6.4, FCU Command Usage.

Table 31.7 FCU Command Formats

Command	Number of bus cycles	First Cycle		Second ycle		Third Cycle		4th to 5th Cycles		6th Cycle		7th to 130th Cycles		131st Cycle	
		Address	Data	Address	Data	Address	Data	Address	Data	Address	Data	Address	Data	Address	Data
P/E normal mode transition	1	RA	FFh	—	—	—	—	—	—	—	—	—	—	—	—
Status read mode transition	1	RA	70h	—	—	—	—	—	—	—	—	—	—	—	—
Lock bit read mode transition (lock bit read 1)	1	RA	71h	—	—	—	—	—	—	—	—	—	—	—	—
Peripheral clock notification	6	RA	E9h	RA	03h	RA	0F0Fh	RA	0F0Fh	RA	D0h	—	—	—	—
Programming	131	RA	E8h	RA	80h	WA	WDn	RA	WDn	RA	WDn	RA	WDn	RA	D0h
Block erasure	2	RA	20h	BA	D0h	—	—	—	—	—	—	—	—	—	—
P/E suspension	1	RA	B0h	—	—	—	—	—	—	—	—	—	—	—	—
P/E resumption	1	RA	D0h	—	—	—	—	—	—	—	—	—	—	—	—
Status register clearing	1	RA	50h	—	—	—	—	—	—	—	—	—	—	—	—
Lock bit read 2	2	RA	71h	BA	D0h	—	—	—	—	—	—	—	—	—	—
Lock bit programming	2	RA	77h	BA	D0h	—	—	—	—	—	—	—	—	—	—

Address column RA:ROM programming/erasure address
When the FENTRY0 bit in FENTRYR is 1: An address from 00FC 0000h to 00FF FFFFh
WA:ROM programming-destination address
Start address for programming of 256 bytes of data
BA:ROM erasure block address
An address within the target erasure block
(specified as an address in the range for programming and erasure)
Data column WDn:nth word of data for programming (n = 1 to 128)

31.6.3 Connections between FCU Modes and Commands

The sets of FCU commands that can be accepted in each of the FCU modes are fixed. Furthermore, which commands are acceptable in a given FCU mode also depends on the state of the FCU.
Issuing of an FCU command must follow checking of the FCU's state after transitions of the FCU mode.
Commands that are acceptable in the various FCU modes and states are listed in Table 31.8. Issuing a command that is not currently acceptable leads to the FCU being placed in the command-locked state (see section 31.8.2, Error Protection).
Issuing of an FCU command must follow checking of the values of the FRDY, ILGLERR, ERSERR, and PRGERR bits in FSTATR0 and of the FCUERR bit in FSTATR1 after transitions of the FCU mode. Furthermore, the CMDLK bit in FASTAT can be checked to see if an error has occurred. The value of the CMDLK bit in FASTAT is the logical OR of the ILGLERR, ERSERR, and PRGERR bits in FSTATR0 and the FCUERR bit in FSTATR1.

Table 31.8 Acceptable Commands and the State and Mode (ROM P/E Mode) of the FCU

	P/E Normal Mode			Status Read Mode						Lock-Bit Read Mode		
Command	**Programming suspended**	**Erasure suspended**	**Other state**	**Programming or erasure**	**Processing to suspend programming or erasure**	**Lock bit read 2 processing**	**Programming suspended**	**Erasure suspended**	**Command-locked state**	**Other state**	**Programming suspended**	**Erasure suspended**	**Other state**
FSTATR0.FRDY bit	1	1	1	0	0	0	1	1	0/1	1	1	1	1
FSTATR0.SUSRDY bit	0	0	0	1	0	0	0	0	0	0	0	0	0
FSTATR0.ERSSPD bit	0	1	0	0	0/1	0	0	1	0	0	0	1	0
FSTATR0.PRGSPD bit	1	0	0	0	0/1	0	1	0	0	0	1	0	0
FASTAT.CMDLK bit	0	0	0	0	0	0	0	0	1	0	0	0	0
P/E Normal mode transition	A	A	A	X	X	X	A	A	X	A	A	A	A
Status read transition	A	A	A	X	X	X	A	A	X	A	A	A	A
Lock-bit read transition (lock bit read 1)	A	A	A	X	X	X	A	A	X	A	A	A	A
Peripheral clock setting	X	X	A	X	X	X	X	X	X	A	X	X	A
Programming	X	*	A	X	X	X	X	*	X	A	X	*	A
Block erasure	X	X	A	X	X	X	X	X	X	A	X	X	A
P/E suspension	X	X	X	A	X	X	X	X	X	X	X	X	X
P/E resumption	A	A	X	X	X	X	A	A	X	X	A	A	X
Status register clearing	A	A	A	X	X	X	A	A	A	A	A	A	A
Lock bit read 2	A	A	A	X	X	X	A	A	X	A	A	A	A
Lock bit programming	X	*	A	X	X	X	X	*	X	A	X	*	A

A: Acceptable
*: Only programming is acceptable for blocks other than the block where erasure was suspended
X: Not acceptable

31.6.4 FCU Command Usage

The set of FCU commands consists of commands for FCU mode transitions, actually programming or erasing the ROM, error processing, and suspension and resumption. The following passages describe the various commands. For a description of the modes and states where the respective commands are acceptable, see section 31.6.3, Connections between FCU Modes and Commands.

31.6.4.1 Mode Transitions

This subsection covers the commands for mode transitions. For an illustration of the various transitions between modes, see Figure 31.5.

(1) Switching to ROM P/E Mode

A transition to ROM P/E mode is required before executing an FCU command for the ROM becomes possible.
Setting the FENTRY0 bit in FENTRYR to 1 causes a transition to ROM P/E mode for programming and erasure of the corresponding address range.
Before actually proceeding to program or erase the ROM, enable programming and erasure by writing 01h as a byte to FWEPROR (see section 31.2.15, Flash Write Erase Protection Register (FWEPROR)).

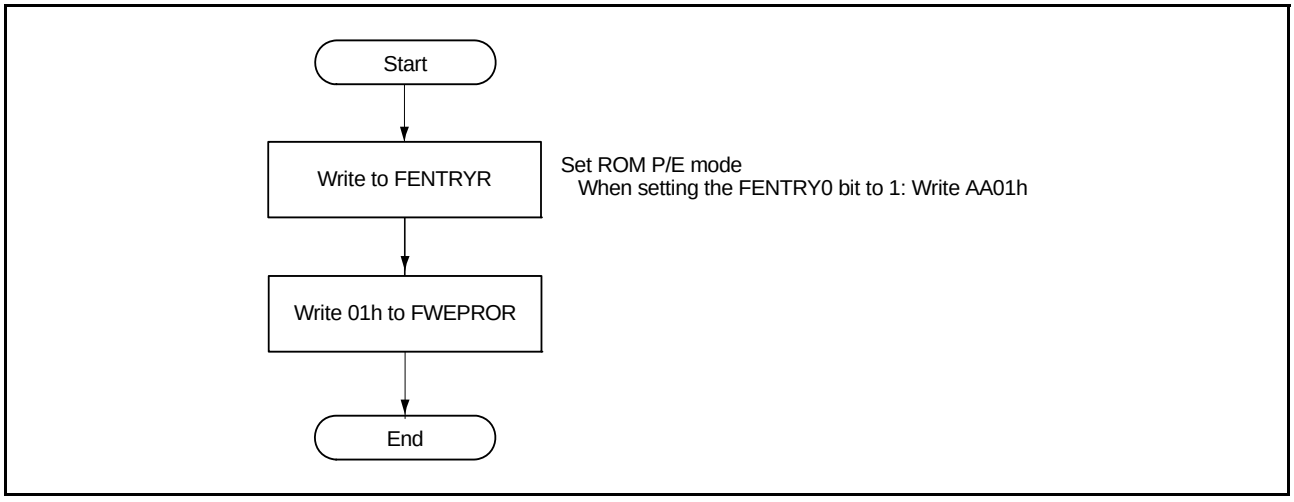


Figure 31.6 Procedure for Transition to ROM P/E Mode

(2) Switching to ROM Read Mode

High-speed reading of the ROM requires clearing of the FENTRY0 bit in FENTRYR, which places the FCU in ROM read mode.
Writing of 02h to FWEPROR is also required to disable programming and erasure (see section 31.2.15, Flash Write Erase Protection Register (FWEPROR)).
Before switching the FCU from P/E mode to read mode, ensure that all processing of FCU commands has been completed and that the FCU has not detected an error.

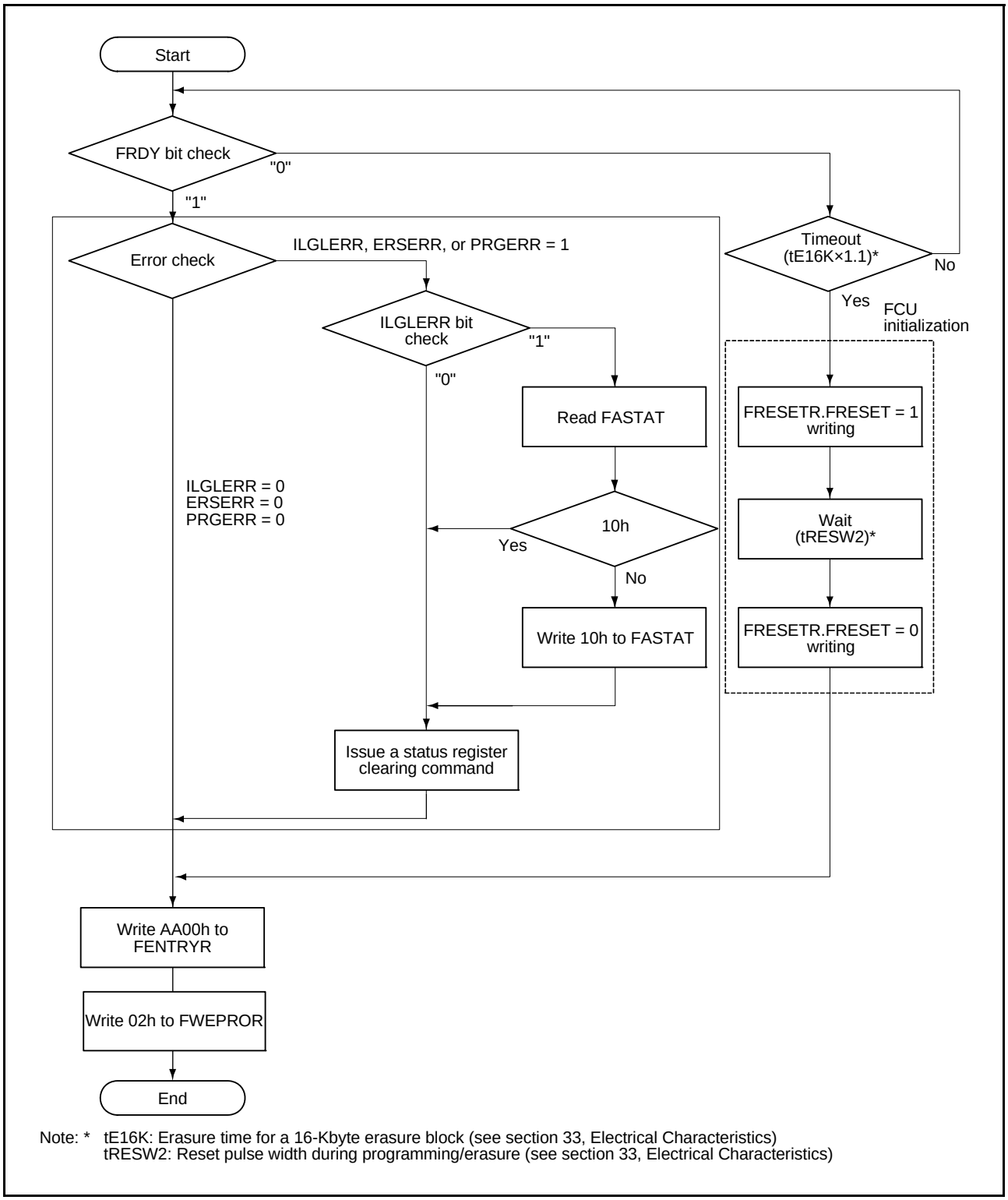


Figure 31.7 Procedure for Transition to ROM Read Mode

(3) Switching to ROM P/E Normal Mode

Two methods are available for the transition to ROM P/E normal mode: setting the FENTRYR register while the FCU is in ROM read mode (see section 31.6.1, FCU Modes), or issuing the normal mode transition command while the FCU is in ROM P/E mode (see Figure 31.8). The normal mode transition command is issued by writing FFh as a byte to an address in the range for programming and erasure of the ROM.

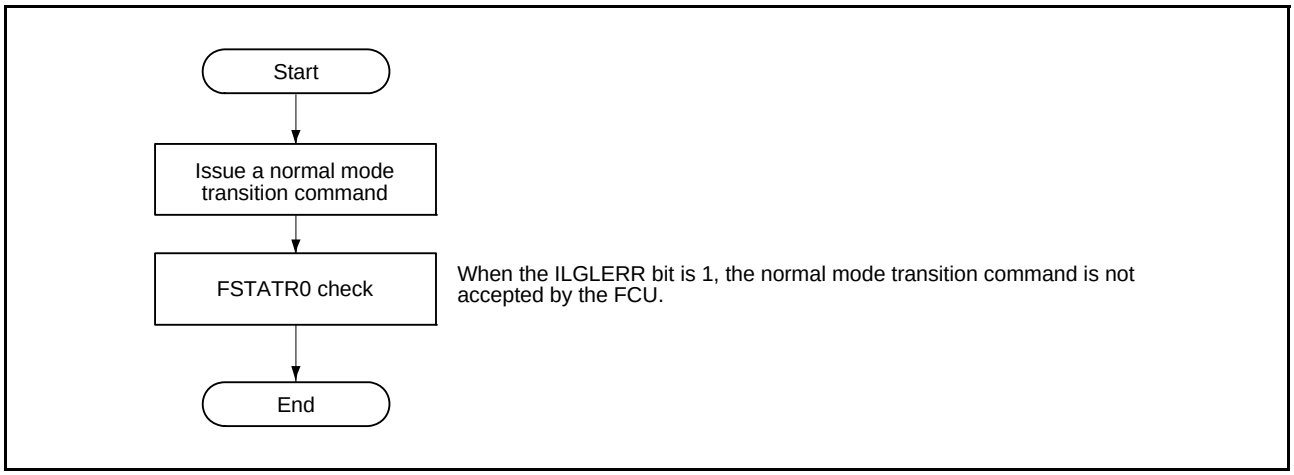


Figure 31.8 Procedure for Transition to ROM P/E Normal Mode

(4) Switching to ROM Status Read Mode

Issuing an FCU command other than a normal mode transition or lock bit read mode transition command places the FCU in ROM status read mode. The same transition can be obtained by issuing the status read mode transition command. Figure 31.9 shows the procedure for checking the register FSTATR0 as an example. In the example, the status read mode transition command is issued to place the FCU in ROM status read mode, and the value of FSTATR0 is obtained by read access to the area for programming and erasure and then checked.

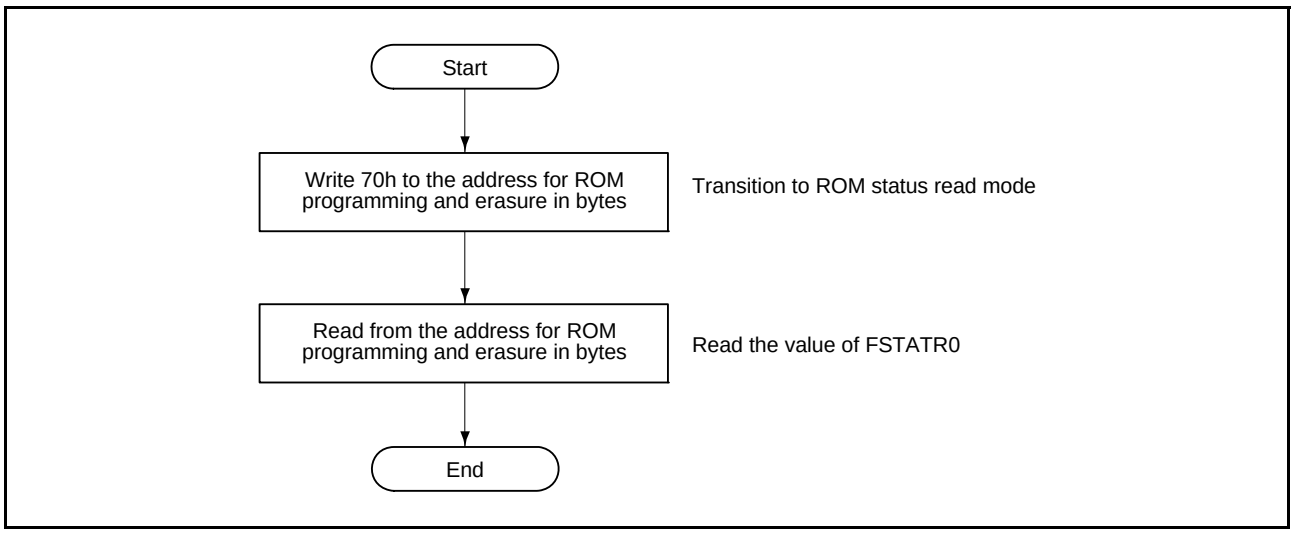


Figure 31.9 Procedure for Transition to ROM Status Read Mode and the Status Checking

(5) Switching to ROM Lock-Bit Read Mode

Clearing the FRDMD bit in FMODR (memory area method) issues a lock bit read mode transition (lock bit read 1) command. After the transition to ROM lock bit read mode, lock bit value are obtained by read access to the area for ROM programming and erasure. All bits of a value thus read out have the value of the lock bit of the erasure block that contains the accessed address (Figure 31.10).

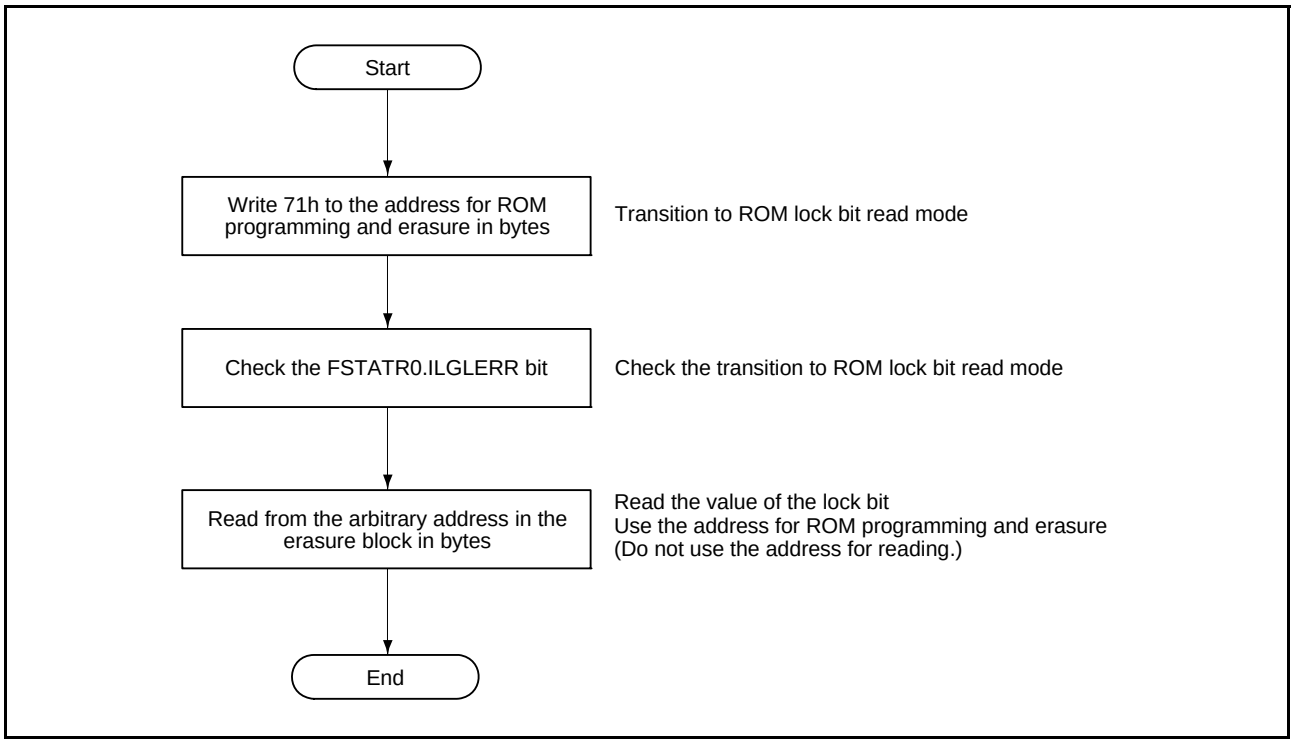
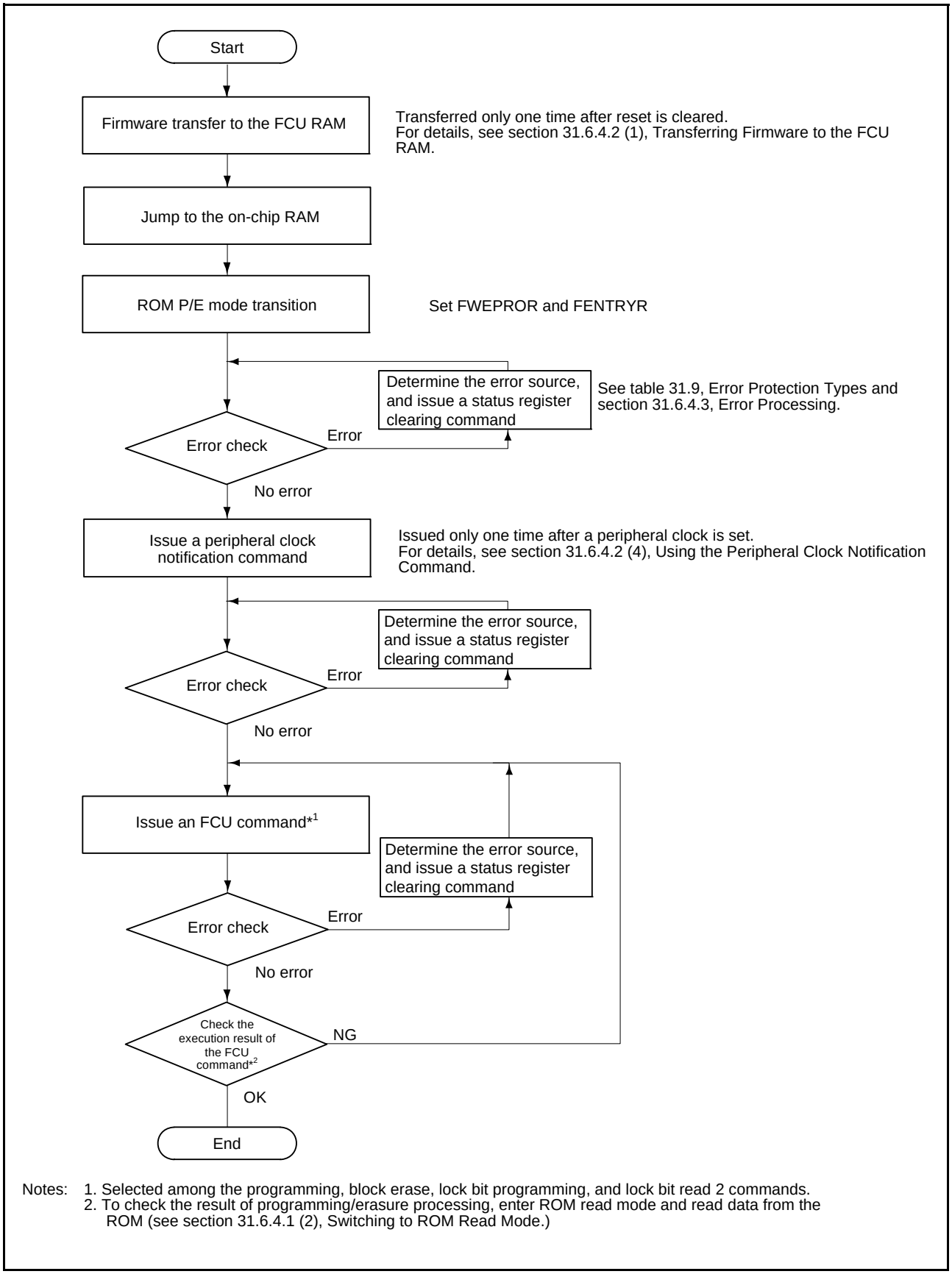


Figure 31.10 Procedure for Transition to ROM Lock-Bit Read Mode and the Lock-Bit Read Method

31.6.4.2 Programming and Erasure Procedures

The following passages describe the flow of procedures for programming or erasing the ROM. For details on the acceptance of commands by the FCU, see section 31.6.3, Connections between FCU Modes and Commands. Figure 31.11 is a simple flowchart of the procedure for executing FCU commands.



Notes: 1. Selected among the programming, block erase, lock bit programming, and lock bit read 2 commands.
2. To check the result of programming/erasure processing, enter ROM read mode and read data from the ROM (see section 31.6.4.1 (2), Switching to ROM Read Mode.)

Figure 31.11 Simple Flowchart of the Procedure for Programming and Erasure

(1) Transferring Firmware to the FCU RAM

FCU commands can only be used if the FCU RAM holds the firmware for the FCU. The FCU RAM does not hold the FCU firmware immediately after the chip has been booted up, so the firmware must be copied from the FCU firmware area to the FCU RAM. Furthermore, when the FCUERR bit in FSTATR1 is set to 1, the FCU must be reset and the firmware recopied because the firmware stored in the FCU RAM may have been corrupted.
Figure 31.12 shows the flow of the procedure for transferring firmware to the FCU RAM. Before writing data to the FCU RAM, set FENTRYR to 0000h and stop the FCU.

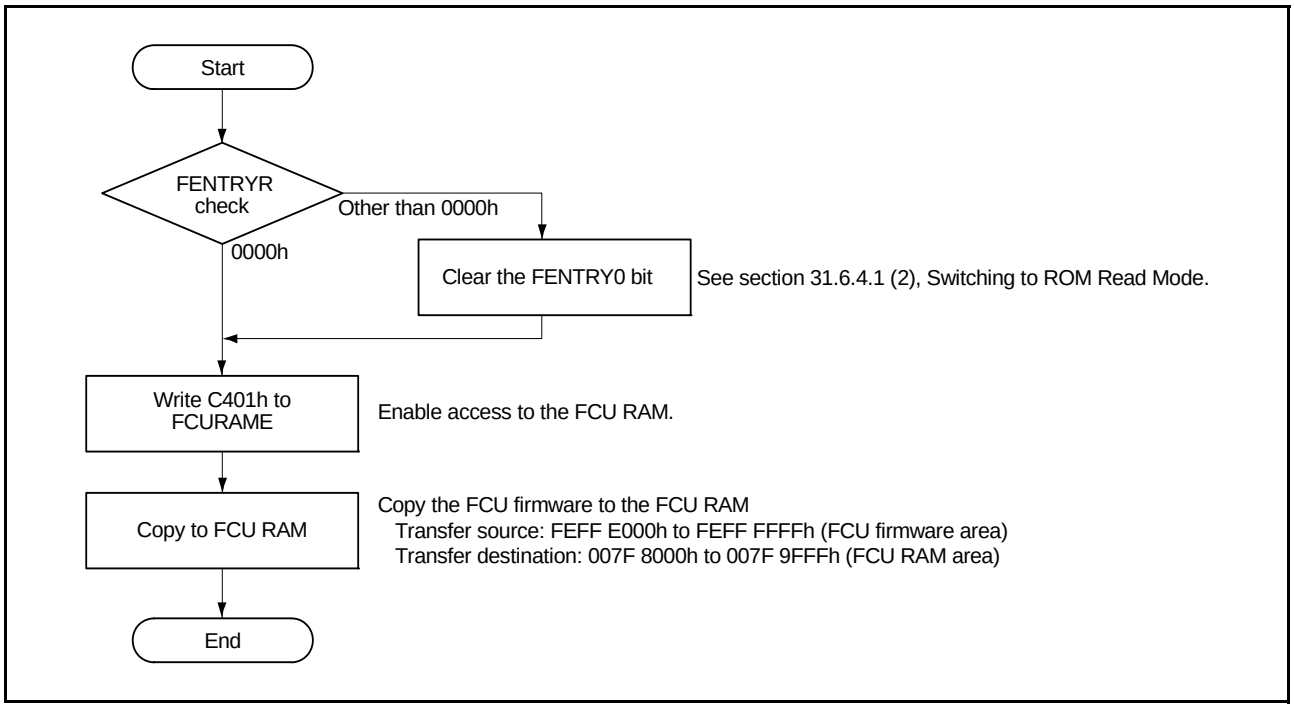


Figure 31.12 Procedure for Firmware Transfer to FCU RAM

(2) Jumping to Locations in On-chip RAM

Since fetching instructions from the ROM is not possible while the ROM is being programmed or erased, code has to be executed from an area other than the ROM. Copy the required program code to on-chip RAM and then make execution jump to the address where the code starts in on-chip RAM.

(3) Transition to ROM P/E Mode

The FCU is placed in ROM P/E mode by the settings of the FENTRY0 bit in FENTRYR and of FWEPROR. Details are given in section 31.6.4.1 (1) Switching to ROM P/E Mode.

(4) Using the Peripheral Clock Notification Command

The peripheral clock is used in programming and erasing the ROM, so the frequency of this clock has to be set in the PCKAR. Frequencies in the range from 8 to 50 MHz are selectable.Make sure to set a frequency within this range.

If a frequency within this range has not been set, the FCU will detect the error and enter the command-blocked state (see section 31.8.2, Error Protection).

The peripheral clock notification command is used after the PCKAR setting has been made. In the first and second cycles for the peripheral clock notification command, respectively, the values E9h and 03h are written to the address range for programming and erasure of the ROM. Word-unit writing is used in the third to fifth cycles of the command. Accordingly, make sure that the addresses used are aligned with four-byte boundaries. After 0F0Fh has been written three times (as a word) to the address range for programming and erasure of the ROM, the process of the FCU setting the frequency of the peripheral clock starts once the value D0h has been written as a byte in the sixth cycle. The FRDY bit in FSTATR0 can be used to check whether or not the settings have been completed.

Addresses that can be used in the first to sixth cycles differ according to the setting of the FENTRY0 bit in FENTRYR. Ensure that the addresses suit the setting of the bit. If issuing of the command is attempted with an erroneous combination of the setting of the bit and specified addresses, the FCU will detect the error and enter the command-blocked state (see section 31.8.2, Error Protection).

Furthermore, if the setting for the peripheral clock in use will not be changed from this setting after release from the reset state, this setting is also valid for the next FCU command.

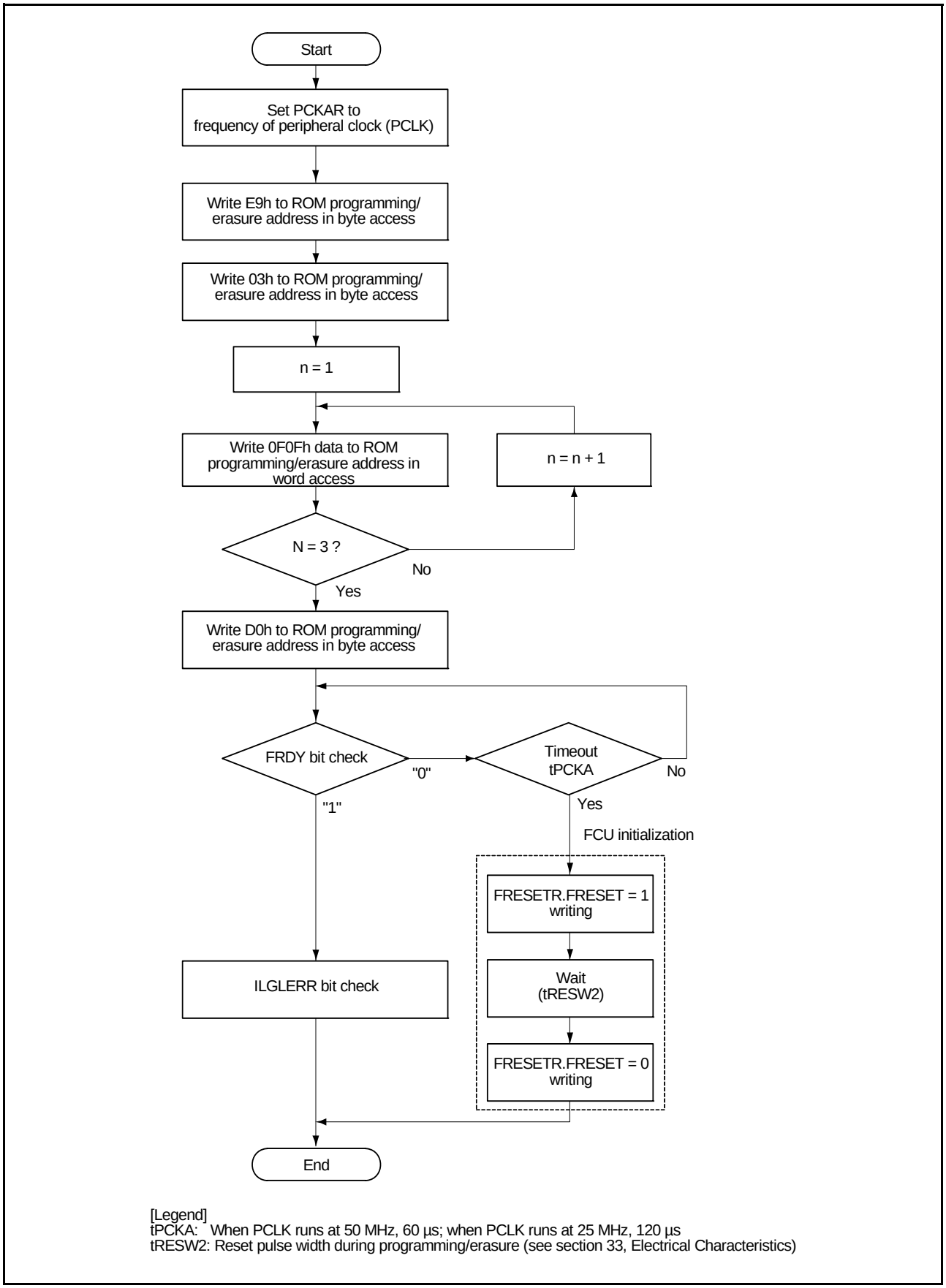
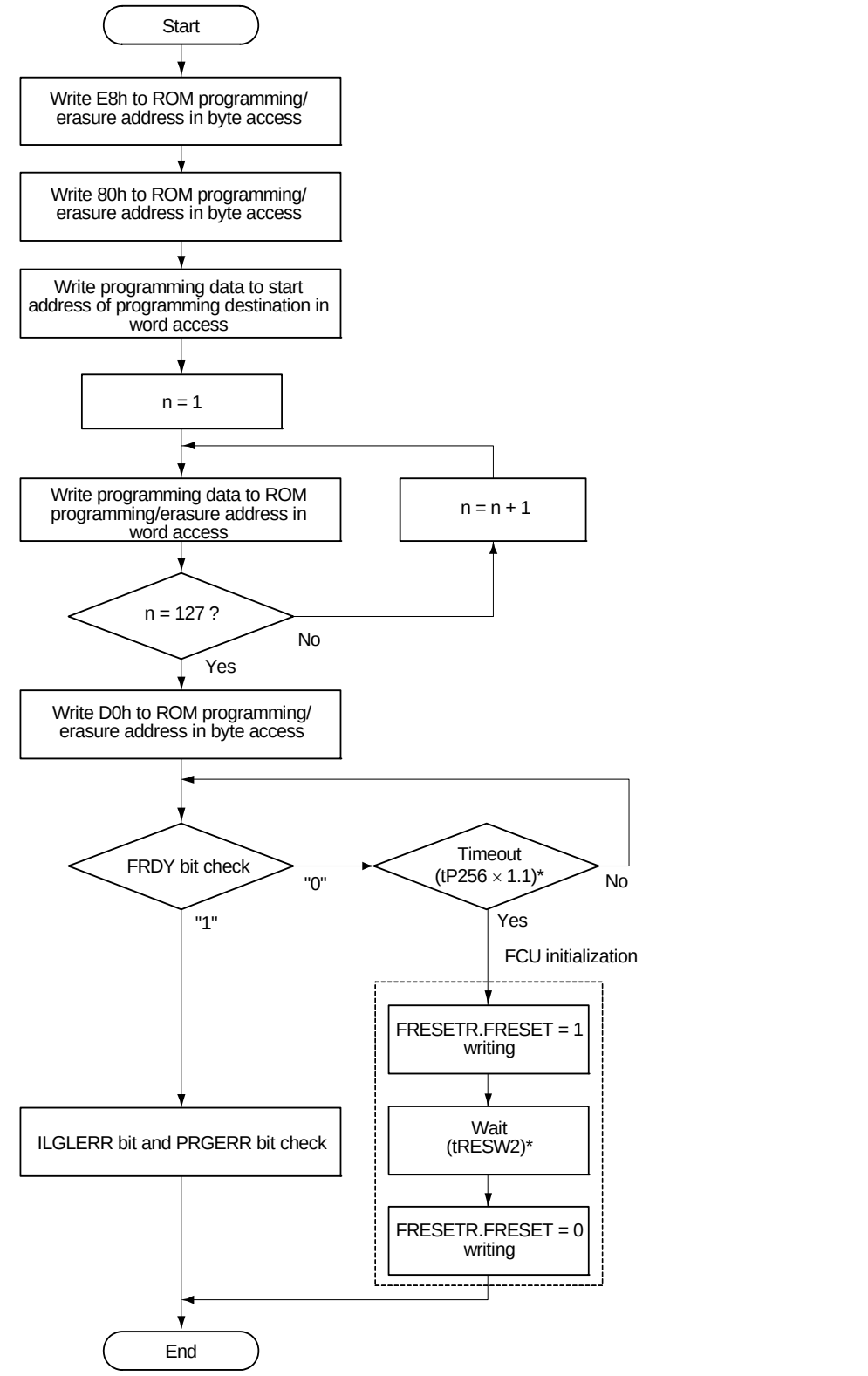


Figure 31.13 Using the Peripheral Clock Notification Command

(5) Programming

The programming command is used to write data to the ROM.
In the first and second cycles for the peripheral clock notification command, respectively, the values E8h and 80h are written to the address range for programming and erasure of the ROM. In the third cycle, write the actual data to be programmed, as a word unit, to the target address for programming. For this first address, always use an address that is on a 256-byte boundary. In the fourth to the 130th cycles, write the data for programming in 127 word-unit rounds to the address range for programming and erasure of the ROM. Once the value D0h has been written as a byte to the address range for programming and erasure of the ROM in the 131st cycle, the FCU begins the actual process of programming the ROM. The FRDY bit in FSTATR0 can be used to check whether or not the programming has been completed.
Addresses that can be used in the first to 131st cycles differ according to the setting of the FENTRY0 bit in FENTRYR. Ensure that the addresses suit the setting of the bit. If issuing of the command is attempted with an erroneous combination of the setting of the bit and specified addresses, the FCU will detect the error and enter the command-blocked state (see section 31.8.2, Error Protection).
In cases where the target range in the third to 130th cycles includes addresses that do not require programming, use FFFFh as the data for programming to those addresses. To execute a programming with lock bit protection disabled, proceed with programming after setting the FPROTCN bit in FPROTR.

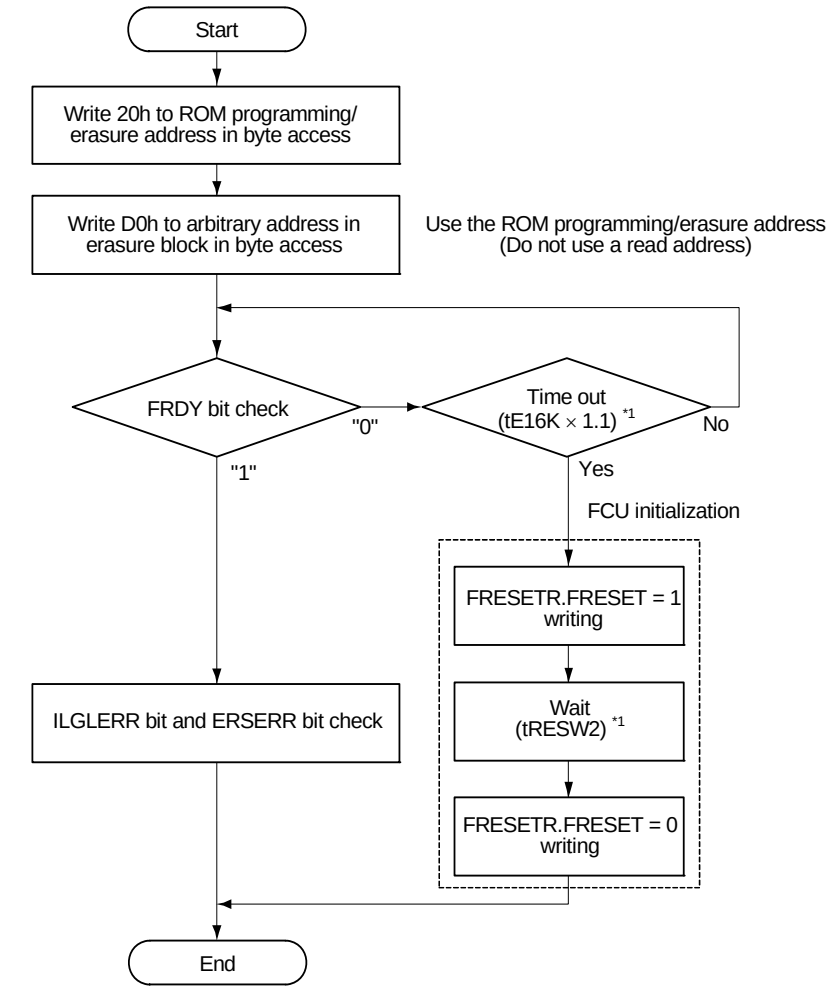


Note: * tP256: Programming time for 256-byte data (see section 33, Electrical Characteristics)
tRESW2: Reset pulse width during programming/erasure (see section 33, Electrical Characteristics)

Figure 31.14 Procedure for ROM Programming

(6) Erasure

To erase data from the ROM, use the block erase command.
Write 20h to the ROM programming/erasure address in byte access in the first cycle of the block erase command. When D0h is written to an arbitrary address in an erasure target block in byte access in the second cycle, the FCU start the erasure processing for the ROM. Whether erasure is completed can be checked with the FRDY bit in FSTATR0. The ROM in the erased state can be read by the CPU as FFFF FFFFh in 32-bit access.
To execute an erasure with lock bit protection disabled, set the FPROTCN bit in FPROTR before erasure.

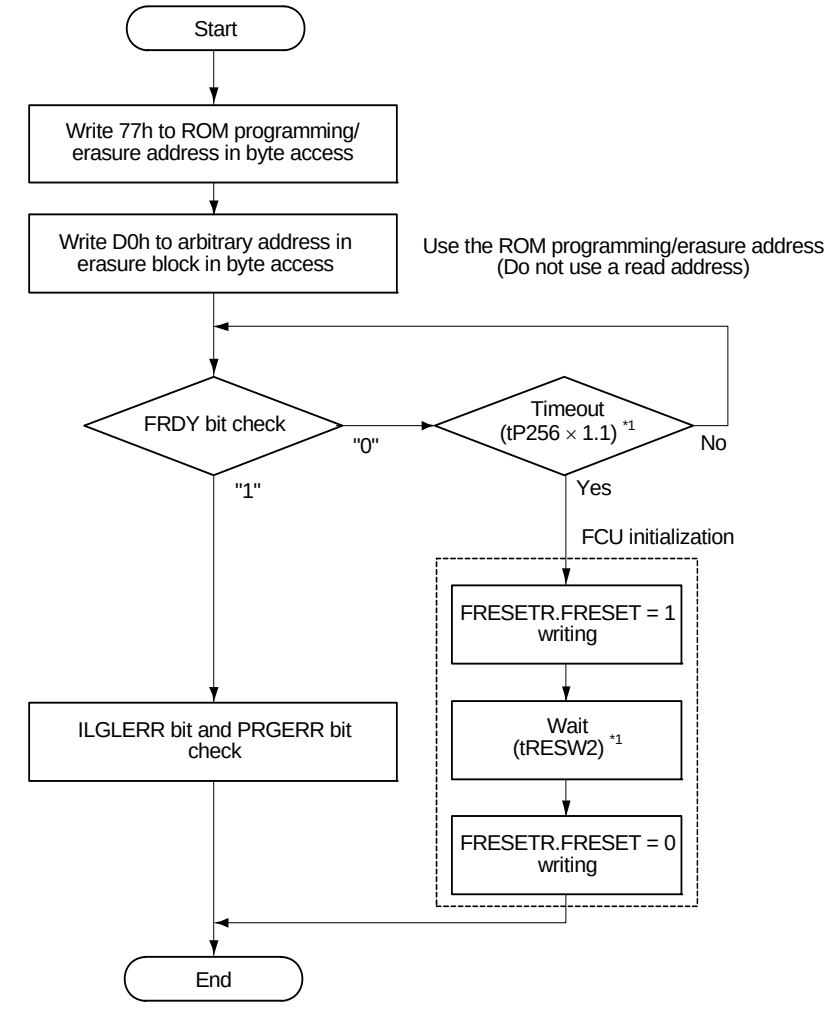


Note 1. tE16K: Erasure time for a 16-Kbyte erasure block (see section 33, Electrical Characteristics)
tRESW2: Reset pulse width during programming/erasure (see section 33, Electrical Characteristics)

Figure 31.15 Procedure for ROM Erasure

(7) Writing to/Erasing Lock Bit

Each erasure block in the user area includes a lock bit. To write to a lock bit, use the lock bit programming command. In the first cycle of the lock bit programming command, 77h is programmed to the ROM programming/erasure address in byte access. When D0h is programmed to an arbitrary address in an erasure block whose lock bit is to be programmed in the second cycle in byte access, the FCU start the programming processing of the lock bit. Whether programming is completed can be checked with the FRDY bit in FSTATR0.



Note 1. tP256: Programming time for 256-byte data (see section 33, Electrical Characteristics)
tRESW2: Reset pulse width during programming/erasure (see section 33, Electrical Characteristics)

Figure 31.16 Procedure for Writing to the Lock Bit

To erase a lock bit, use the block erase command.
When the FPROTCN bit in FPROTR is 0, erasure blocks whose lock bit is set to 0 cannot be erased. When erasing a lock bit, issue a block erase command with the FPROTCN bit set to 1. Using the block erase command erases all data in the erasure block. It is impossible to erase only a lock bit.

(8) Reading Lock Bits

Lock bits can be read out by either reading from a memory area or reading from a register.
The lock bit read 2 command is issued in the case of the register-reading method (i.e. when the FRDMD bit in FMODR is 1). This command is issued to an address within the block for which the lock bit is to be read out; the address range is that for programming and erasing the ROM. In the first and second cycles of the lock bit read 2 command, the values 71h and D0h are written as bytes; once these values have been written, the value of the lock bit for the specified erasure block is copied to the FLOCKST bit in FSTATR1.
In the case of the memory area reading method (i.e. when the FRDMD bit in FMODR is 0), the FCU is placed in lock-bit reading mode, and the lock bit is obtained by reading from an address within the address range for programming and erasure of the ROM. Details are given in section 31.6.4.1 (5) Switching to ROM Lock-Bit Read Mode.

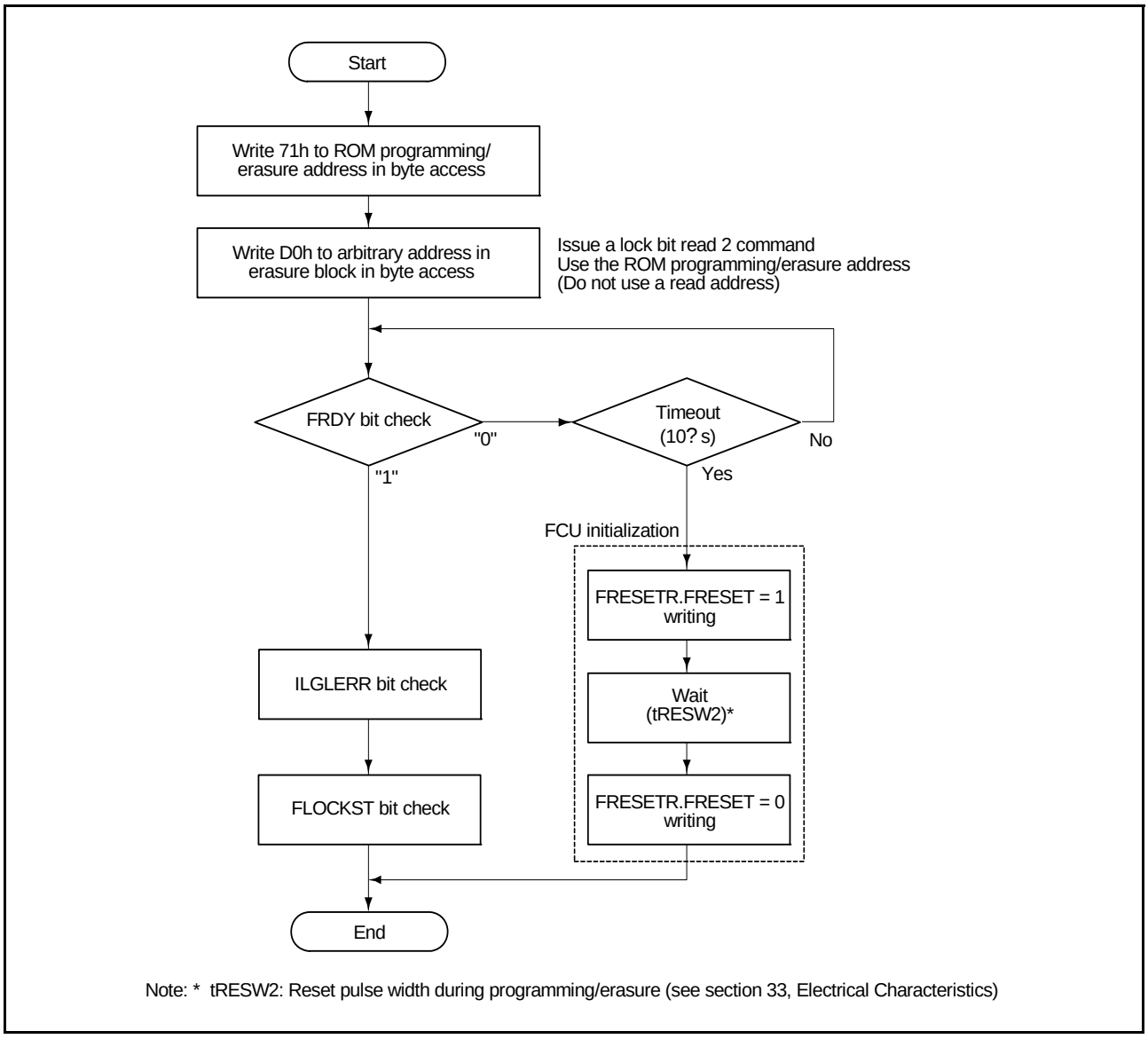


Figure 31.17 Procedure for Reading Lock Bit in Register Read Mode

31.6.4.3 Error Processing

The following passages describe the flow of error processing. For details on errors, see section 31.8, Protection.

(1) Checking Flash Status Register 0 (FSTATR0)

To check FSTATR0, read FSTATR0 directly or read the ROM programming/erasure address in ROM status read mode. For the reading in ROM status read mode, see section 31.6.4.1 (4) Switching to ROM Status Read Mode.

(2) Clearing Flash Status Register 0 (FSTATR0)

To clear the ILGLERR, ERSERR and PRGERR bits in FSTATR0, use the status register clearing command.
When one of the ILGLERR, ERSERR and PRGERR bits in FSTATR0 is 1, the FCU is placed in the command-locked state and receives no FCU commands other than the status register clearing command. If the ILGLERR is 1, also check the values of the ROMAE, DFLAE, DFLRPE, and DFLWPE bits in FASTAT. Even if issuing a status register clearing command without clearing these bits, the ILGLERR bit is not cleared.

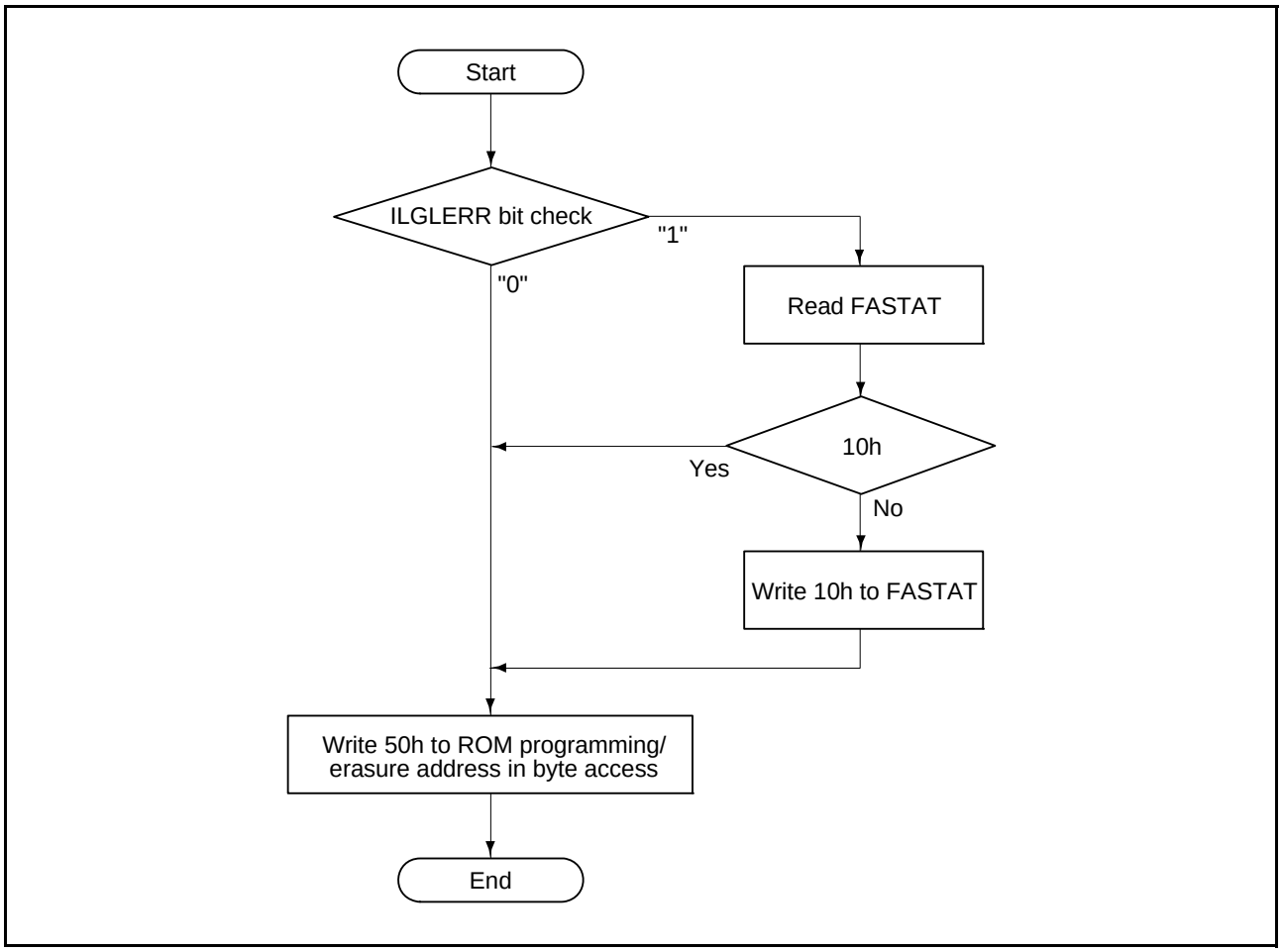


Figure 31.18 Procedure for Clearing FSTATR0

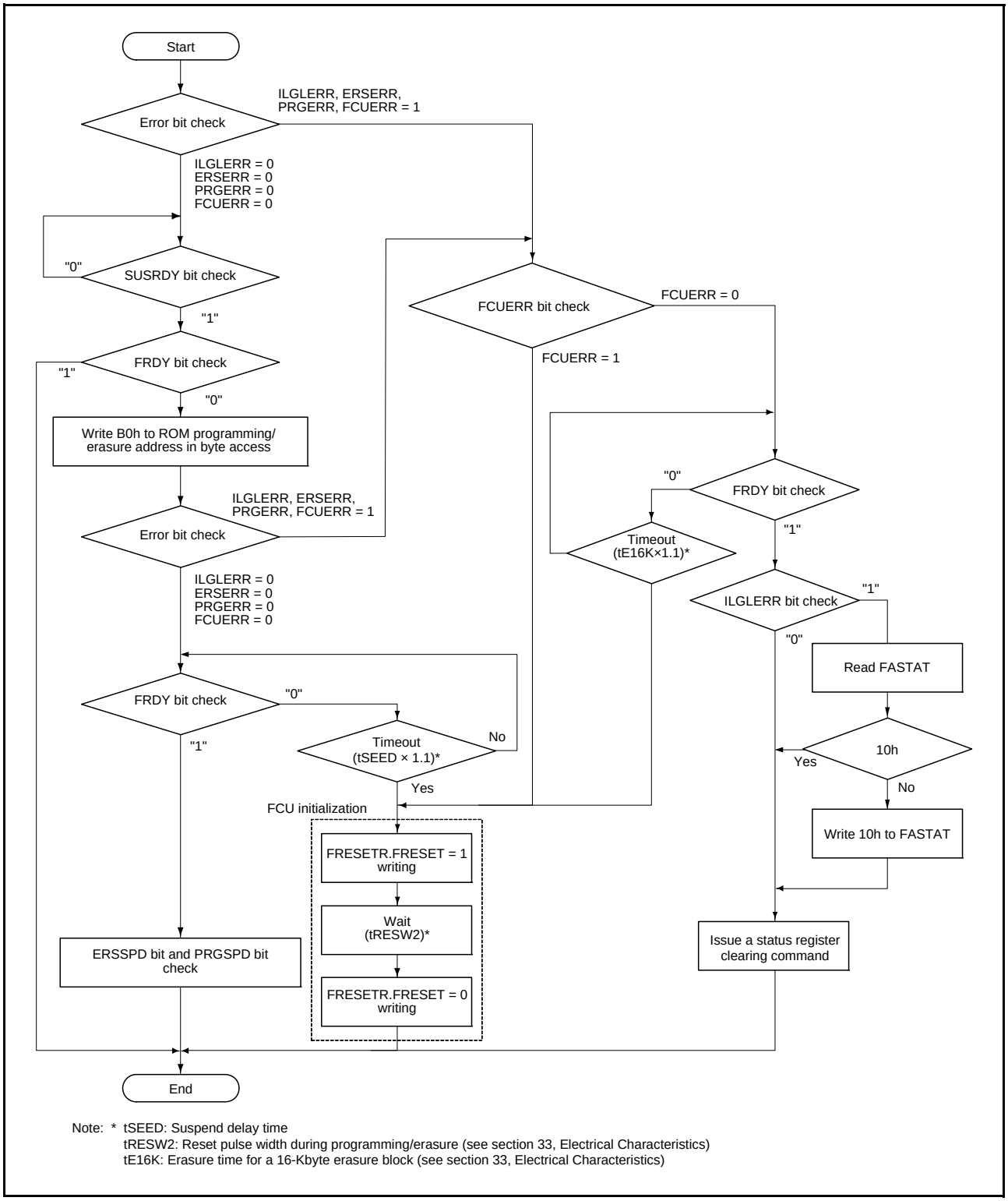
(3) Initializing the FPU

When a timeout leads to the FRDY bit in FSTATR0 not being set to 1 after an FCU command has been issued, FRESETR must be used to initialize the FCU. This is also necessary when the FCUERR bit in FSTATR1 has been set. In either case, maintain the FRESET bit in FRESETR at logical one over a period of at least tRESW2 (see section 33, Electrical Characteristics). Disable reading from the ROM and data-flash memory over this period. In addition, while the FRESET bit is 1, FCU commands are disabled because the FENTRYR register is initialized. Restart the processing from the start, as shown in Figure 31.11.

31.6.4.4 Suspension and Resumption

(1) Suspending Programming or Erasure

To suspend programming/erasure for the ROM, use the P/E suspend command.
When issuing a P/E suspend command, check that the ILGLERR, ERSERR, and PRGERR bits in FSTATR0 and the FCUERR bit in FSTATR1 are 0, and the execution of programming/erasure is normally performed. To confirm that the suspend command can be received, also check that the SUSRDY bit in FSTATR0 is 1. After issuing a P/E suspend command, read FSTATR0 and FSTATR1 to confirm that no error occurs.
If an error occurs during programming/erasure, at least one of the ILGLERR, PRGERR, ERSERR, and FCUERR bits is set to 1. When programming/erasure processing has finished during the interval from when it is checked that the SUSRDY bit is 1 to when a P/E suspend command is received, the ILGLERR bit is set to 1 because the issued P/E suspend command is detected as an illegal command.
When programming/erasure processing has finished simultaneously with the reception of a P/E suspend command, no error occurs and the suspended state is not entered (the FRDY bit in FSTATR0 is 1 and the ERSSPD and PRGSPD bits in FSTATR0 are 0). When a P/E suspend command is received and then the programming/erasure suspend processing finishes normally, the FCU enters the suspended state, the FRDY bit is set to 1, and the ERSSPD or PRGSPD bit is set to 1. After issuing a P/E suspend command, check that the ERSSPD or PRGSPD bit is 1 and the FCU enters the suspended state, and then decide the subsequent flow. When issuing a P/E resume command in the subsequent flow although the FCU does not enter the suspended state, an illegal command error occurs and the FCU is placed in the command-locked state (see section 31.8.2, Error Protection).
If the erasure suspended state is entered, programming to blocks other than an erasure target can be performed. Additionally, the programming and erasure suspended states can change to ROM read mode by clearing FENTRYR.
For details on FCU operations at the reception of a P/E suspend command, see section 31.7, Suspending Operation.

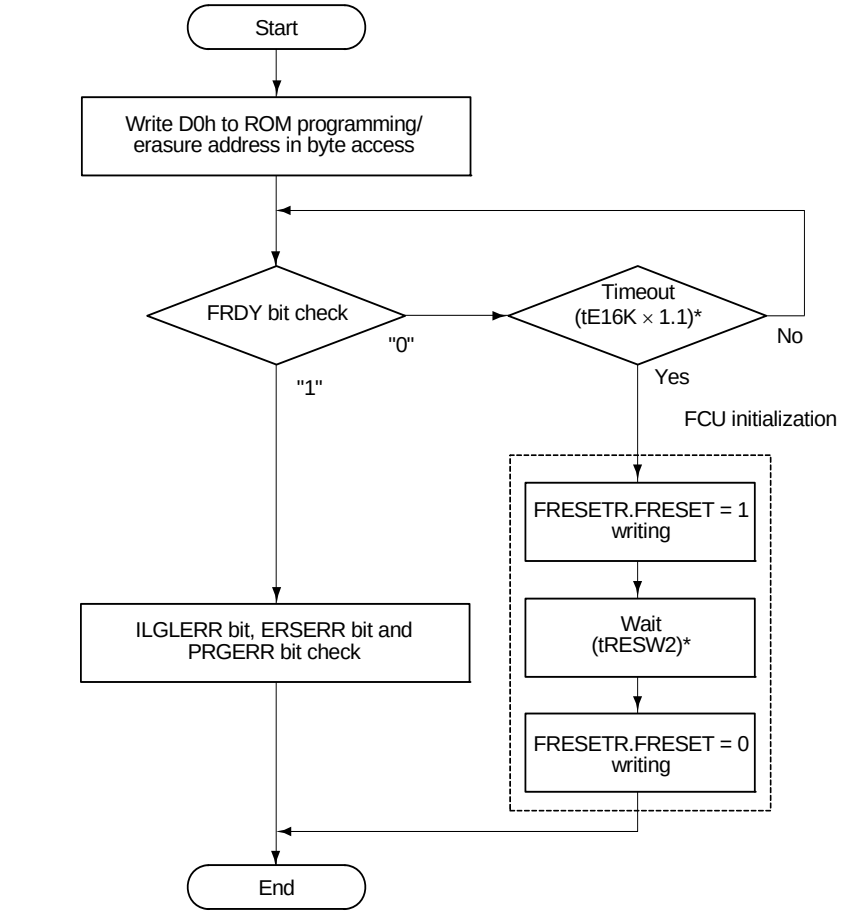


Note: * tSEED: Suspend delay time
tRESW2: Reset pulse width during programming/erasure (see section 33, Electrical Characteristics)
tE16K: Erasure time for a 16-Kbyte erasure block (see section 33, Electrical Characteristics)

Figure 31.19 Procedure for Programming/Erasure Suspension

(2) Resuming Programming or Erasure

To resume a suspended programming/erasure processing, use the P/E resume command. When the settings of FENTRYR are changed during suspension, reset FENTRYR to the value immediately before a P/E suspend command is issued, and then issue a P/E resume command.



Note: * tE16K: Erasure time for a 16-Kbyte erasure block (see section 33, Electrical Characteristics)
tRESW2: Reset pulse width during programming/erasure (see section 33, Electrical Characteristics)

Figure 31.20 Procedure for Resuming Programming or Erasure

31.7 Suspending Operation

The ROM cannot be read out during programming/erasure. The ROM can be read out by suspending the ROM programming/erasure with the P/E suspend command. The P/E suspend command includes one programming mode and two erasure modes (suspension priority mode and erasure priority mode). The P/E resume command that resumes suspended programming/erasure processing is also provided.

31.7.1 Suspension during Programming

When issuing a P/E suspend command during the ROM programming/erasure, the FCU suspends programming processing. Figure 31.21 shows the suspend operation of programming.
When receiving a programming-related command, the FCU clears the FRDY bit in FSTATR0 to 0 to start programming. If the FCU enters the state in which the P/E suspend command can be received after starting programming, the SUSRDY bit in FSTATR0 is set to 1. When a P/E suspend command is issued, the FCU receives the command and clears the SUSRDY bit to 0. If the FCU receives a P/E suspend command while a programming pulse is being applied, the FCU continues applying the pulse. After specified pulse application time, the FCU finishes pulse application, and starts the programming suspend processing and sets the PRGSPD bit in FSTATR0 to 1. When the suspend processing finishes, the FCU sets the FRDY bit to 1 to enter the programming suspended state. If receiving a P/E resume command in the programming suspended state, the FCU clears the FRDY and PRGSPD bits to 0 and resumes programming.

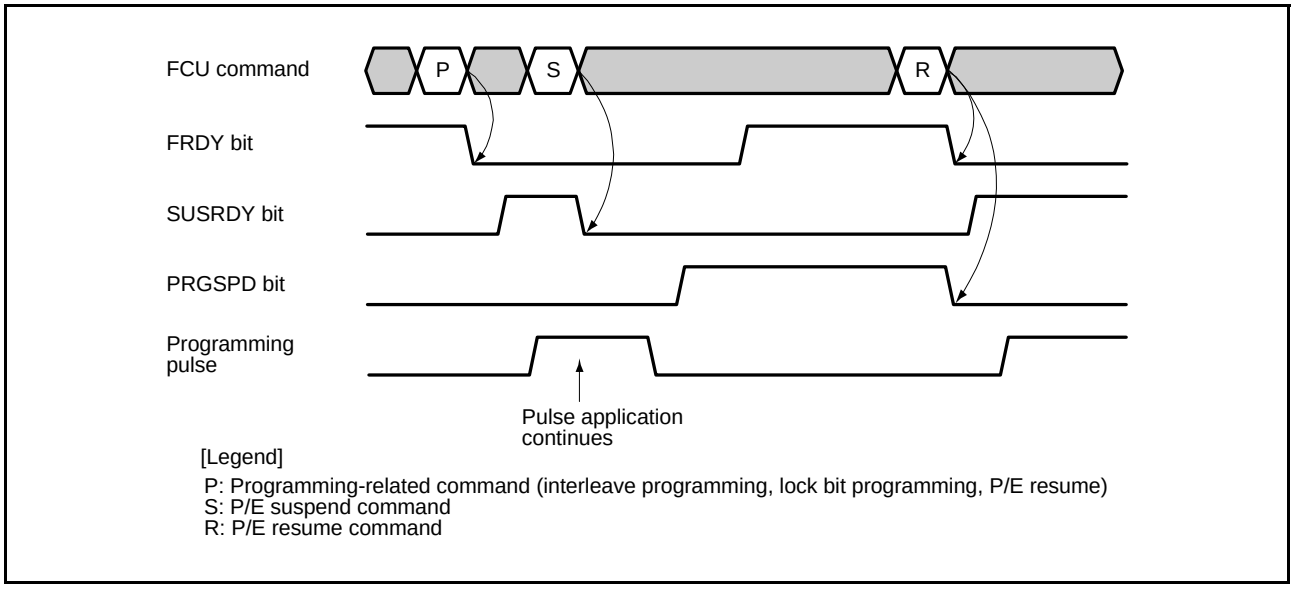


Figure 31.21 Suspension during Programming

31.7.2 Suspension during Erasure (Suspension Priority Mode)

Figure 31.22 shows the suspend operation of erasure when the erasure suspend mode is set to the suspension priority mode (ESUSPMD bit in FCPSR is 0).

When receiving an erasure-related command, the FCU clears the FSTATR0.FRDY bit to 0 to start erasure. If the FCU enters the state in which the P/E suspend command can be received after starting erasure, the FSTATR0.SUSRDY bit is set to 1. When a P/E suspend command is issued, the FCU receives the command and clears the SUSRDY bit to 0. When receiving a suspend command during erasure, the FCU starts the suspend processing and sets the ERSSPD bit in FSTATR0 to 1 even if it is applying an erasure pulse. When the suspend processing finishes, the FCU sets the FRDY bit to 1 to enter the erasure suspended state. If receiving a P/E resume command in the erasure suspended state, the FCU clears the FRDY and ERSSPD bits to 0 and resumes erasure. Operations of the FRDY, SUSRDY, and ERSSPD bits at the suspension and resume of erasure are the same, regardless of the erasure suspend mode.

The setting of the erasure suspend mode affects the control method of erasure pulses. In suspension priority mode, when receiving a P/E suspend command while erasure pulse A that has never been suspended in the past is being applied, the FCU suspends the application of erasure pulse A and enters the erasure suspended state. When receiving a P/E suspend command while reapplying erasure pulse A after erasure is resumed by a P/E resume command, the FCU continues applying erasure pulse A. After specified pulse application time, the FCU finishes erasure pulse application and enters the erasure suspended state. When the FCU receives a P/E resume command next and erasure pulse B starts to be newly applied, and then the FCU receives a P/E suspend command again, the application of erasure pulse B is suspended. In suspension priority mode, delay due to suspend can be minimized because the application of an erasure pulse is suspended one time per pulse and priority is given to the suspension processing.

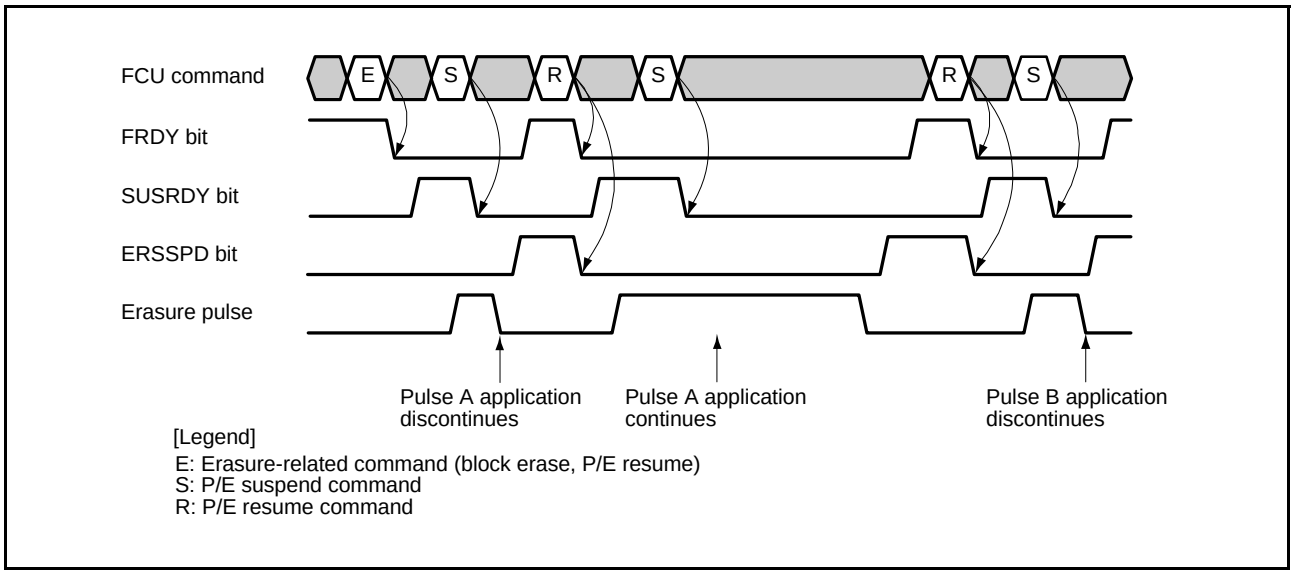


Figure 31.22 Suspension during Erasure (Suspension Priority Mode)

31.7.3 Suspension during Erasure (Erasure Priority Mode)

Figure 31.23 shows the suspend operation of erasure when the erasure suspend mode is set to the erasure priority mode (ESUSPMD bit in FCPSR is 1). The control method of erasure pulses in erasure priority mode is the same as that of programming pulses for the programming suspend processing.

If the FCU receives a P/E suspend command while an erasure pulse is being applied, the FCU definitely continues applying the pulse. In this mode, required time for the whole erasure processing can be reduced as compared with the suspension priority mode because the reapplication of erasure pulses does not occur when a P/E resume command issued.

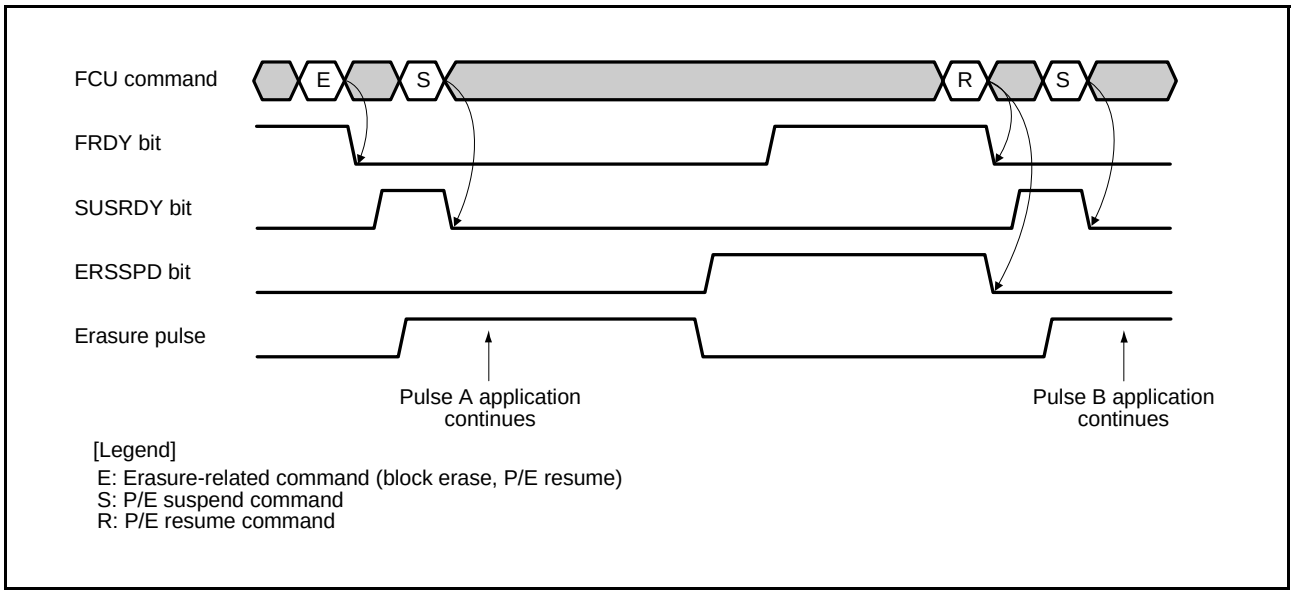


Figure 31.23 Suspension during Erasure (Erasure Priority Mode)

31.8 Protection

Protection against programming/erasure for the ROM includes software protection and error protection.

31.8.1 Software Protection

With the software protection, the ROM programming/erasure is prohibited by the settings of the control register or user area lock bit. When the software protection is violated and a ROM programming/erasure-related command is issued, the FCU detects an error and enters the command-locked state.

(1) Protection through FWEPROR

If the FLWE[1:0] bits in FWEPROR are not set to 01b, programming cannot be performed in any of the modes.

(2) Protection through FENTRYR

When the FENTRY0 bit in FENTRYR is 0, ROM read mode is selected. Because the FCU command cannot be received in ROM read mode, ROM programming/erasure is prohibited. When an FCU command is issued in ROM read mode, the FCU detects an illegal command error and is placed in the command-locked state (see section 31.8.2, Error Protection).

(3) Protection through Lock Bit

Each erasure block in the user area includes a lock bit. When the FPROTCN bit in FPROTR is 0, erasure blocks whose lock bit is set to 0 are prohibited from being programmed/erased. To program or erase erasure blocks whose lock bit is set to 0, set the FPROTCN bit to 1. When the lock bit protection is violated and a ROM programming/erasure-related command is issued, the FCU detects a programming/erasure error and enters the command-locked state (see section 31.8.2, Error Protection).

31.8.2 Error Protection

With the error protection, FCU command issuance errors, prohibited access occurrences, and FCU malfunctions are detected, and an FCU command is prohibited from being received (command-locked state). When the FCU enters the command-locked state (FASTAT.CMDLK bit is 1), one or several of the status bits (FSTATR0.ILGLERR, ERSERR, and PRGERR bits, FSTATR1.FCUERR bit, and FASTAT.ROMAE bit) are set to 1 and programming and erasure of the ROM are prohibited. To clear the command-locked state, a status register clearing command must be issued with FASTAT set to 10h.

While the CMDLKIE bit in FAEINT is set to 1, if the FCU is placed in the command-locked state (CMDLK bit in FASTAT is set to 1), a flash interface error (FIFERR) interrupt occurs. While the ROMAEIE bit in FAEINT is set to 1, if the ROMAE bit in FASTAT is set to 1, an FIFERR interrupt occurs.

Table 31.9 lists the relationship between the contents of the ROM-related error protection and status bit values (ILGLERR, ERSERR, PRGERR bits in FSTATR0, FCUERR bit in FSTATR1, ROMAE bit in FASTAT) at error detection. If a command other than the suspend command is issued during programming/erasure and the FCU enters the command-locked state, it continues the programming/erasure. In this state, it is impossible to issue a P/E suspend command and suspend programming/erasure. When a command is issued in the command-locked state, the ILGLERR bit is set to 1.

Table 31.9 Error Protection Types (Types Dedicated to ROM and Types Common to ROM and Data Flash)

Type	Description	ILGLERR	ERSERR	PRGERR	FCUERR	ROMAE	CMDLK
FENTRYR setting error	More than one bit is set to 1 among the FENTRYD and FENTRY0 bits in FENTRYR	1	0	0	0	0	1
	The FENTRYR setting at suspension disagrees with that at resume	1	0	0	0	0	1
Illegal command error	Undefined code is specified in the first cycle of an FCU command	1	0	0	0	0	1
	Other than D0h is specified in the last cycle of a multi-cycle FCU command	1	0	0	0	0	1
	A command other than the suspend command is issued during programming/erasure	1	0	0	0	0	1
	A suspend command is issued during processing other than programming/erasure	1	0	0	0	0	1
	A suspend command is issued in the suspended state	1	0	0	0	0	1
	A resume command is issued in other than the suspended state	1	0	0	0	0	1
	A programming/erasure-related (programming/lock bit programming/ block erase) command is issued in the programming suspended state	1	0	0	0	0	1
	A block erase command is issued in the erasure suspended state	1	0	0	0	0	1
	A programming or lock bit programming command is issued to an erasure suspend target area in the erasure suspended state	1	0	0	0	0	1
	Other than 80h is specified in the second cycle of the programming command	1	0	0	0	0	1
	A command is issued in the command-locked state	1	0/1	0/1	0/1	0/1	1
Erasure error	An error occurs during erasure	0	1	0	0	0	1
	When the FPROTCN bit in FPROTR is 0, a block erase command is issued to a erasure block whose lock bit is set to 0	0	1	0	0	0	1
Programming error	An error occurs during programming	0	0	1	0	0	1
	When the FPROTCN bit in FPROTR is 0, a programming or lock bit programming command is issued to a erasure block whose lock bit is set to 0	0	0	1	0	0	1
FCU error	An error occurs during FCU internal processing	0	0	0	1	0	1
ROM access violation	When the FENTRY0 bit in FENTRYR is 1 and the FCU is in P/E normal mode, a read command is issued for programming or erasure addresses	1	0	0	0	1	1
	When the FENTRY0 bit in FENTRYR is 0, a command is issued for programming or erasure addresses	1	0	0	0	1	1
	A read command is issued for read addresses when FENTRYR is set to other than 0000h	1	0	0	0	1	1

31.9 Boot Mode

31.9.1 System Configuration

In boot mode, the host sends control commands and data for programming, and the user area and data area are programmed or erased accordingly. An on-chip SCI handles transfer between the host and RX62T in asynchronous mode. Tools for the transmission of control commands and the data for programming must be prepared in the host. When the RX62T is activated in boot mode, the program on the area that holds the embedded program is executed. This program automatically adjusts the bit rate of the SCI and controls programming/erasure in response to control commands received from the host.
Figure 31.24 shows the system configuration for operations in boot mode.

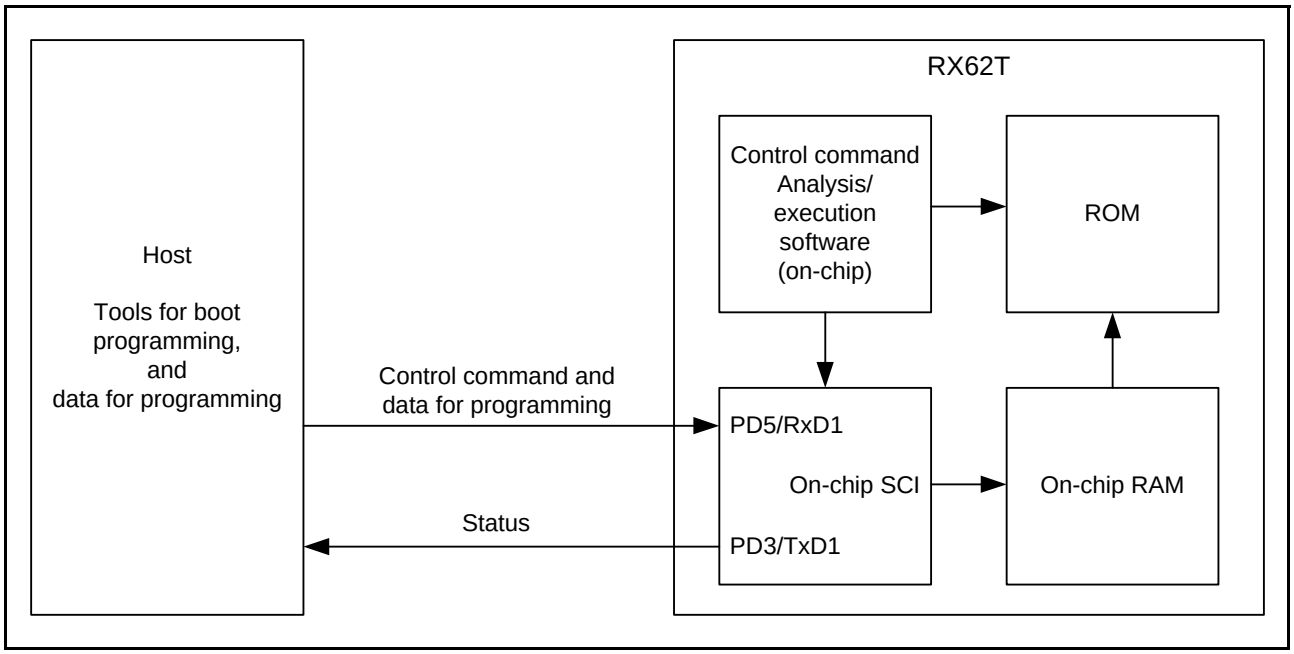


Figure 31.24 System Configuration for Operations in Boot Mode

31.9.2 ID Code Protection

This function is used to prohibit reading/programming/erasure from the host.
Using the control code and ID code written in the ROM, ID code protection is enabled or disabled and ID code protection is judged. When ID code protection is enabled, the code sent from the host is compared with the control code and ID code in the ROM to determine whether they match, and reading/programming/erasure will be enabled only when the two match.
The control code and ID code in the ROM consists of four 32-bit words. Figure 31.25 shows the configuration of the control code and ID code. The ID code should be set in 32-bit units.

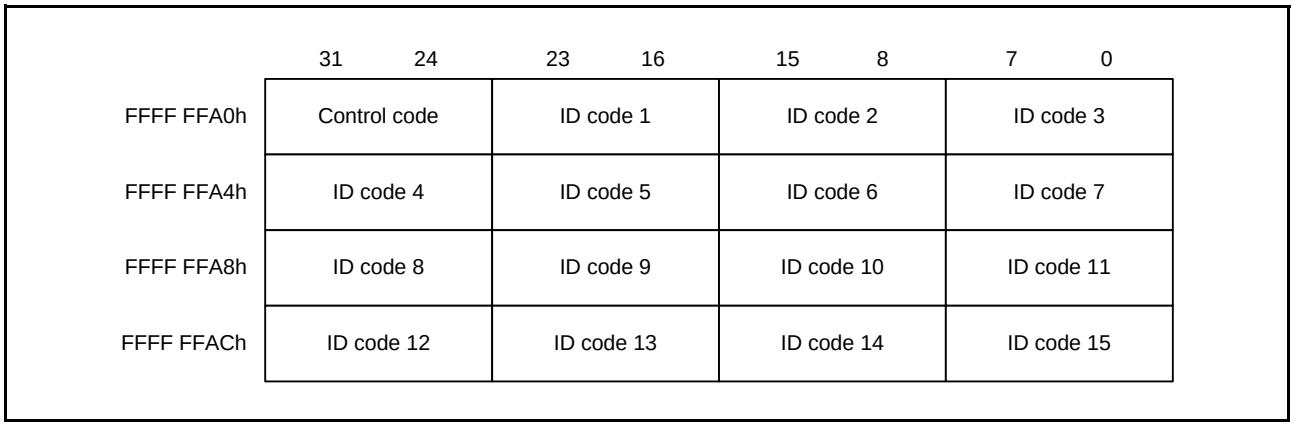


Figure 31.25 Configuration of Control Code and ID Code in ROM

(1) Control Code

The control code determines whether ID code protection is or is not enabled and the method of authentication to use with the host. Table 31.10 shows how the control code determines the method of authentication

Table 31.10 Specifications for ID Code Protection

Control Code	ID Code	State of Protection	Operations at the Time of SCI Connection
45h	As desired	Protection enabled (authentication method 1)	Matching ID code: ID code protection is lifted, and this is followed by a transition to the state of waiting for a host command. Non-matching ID code: Up to two more transitions to the ID code protection waiting state; complete erasure if a non-matching ID code is received for a third time.
52h	Sequences other than 50h, 72h, 6Fh, 74h, 65h, 63h, 74h, FFh, ..., FFh	Protection enabled (authentication method 2)	Matching ID code: ID code protection is lifted, and this is followed by a transition to the state of waiting for a host command. Non-matching ID code: Further transition to the ID code protection waiting state
	50h, 72h, 6Fh, 74h, 65h, 63h, 74h, FFh, ..., FFh	Protection enabled (authentication method 3)	Always judged to be a non-matching ID code.
Other than the above	—	Protection disabled	Erasure of all blocks

(2) ID Code

The ID code can be set to any desired value. However, if the control code is 52h and the ID code is 50h, 72h, 6Fh, 74h, 65h, 63h, 74h, FFh, ..., FFh (from the ID code 1 field), there is no determination of matching and the ID code is always considered to be non-matching. Accordingly, reading, programming, and erasure from the host are prohibited.

(3) Example of Assembler Directives for Setting an ID Code

The following assembler directives set up a control code of 45h and an ID code of 01h, 02h, 03h, 04h, 05h, 06h, 07h, 08h, 0Ah, 0Bh, 0Ch, 0Dh, 0Eh, 0Fh (from the ID code 1 field).

```
.SECTION    ID_CODE,CODE
.ORG        0FFFFFFA0h
.LWORD      45010203h
.LWORD      04050607h
.LWORD      08090A0Bh
.LWORD      0C0D0E0Fh
```

31.9.3 State Transitions in Boot Mode

Figure 31.26 is a diagram of the state transitions in boot mode.

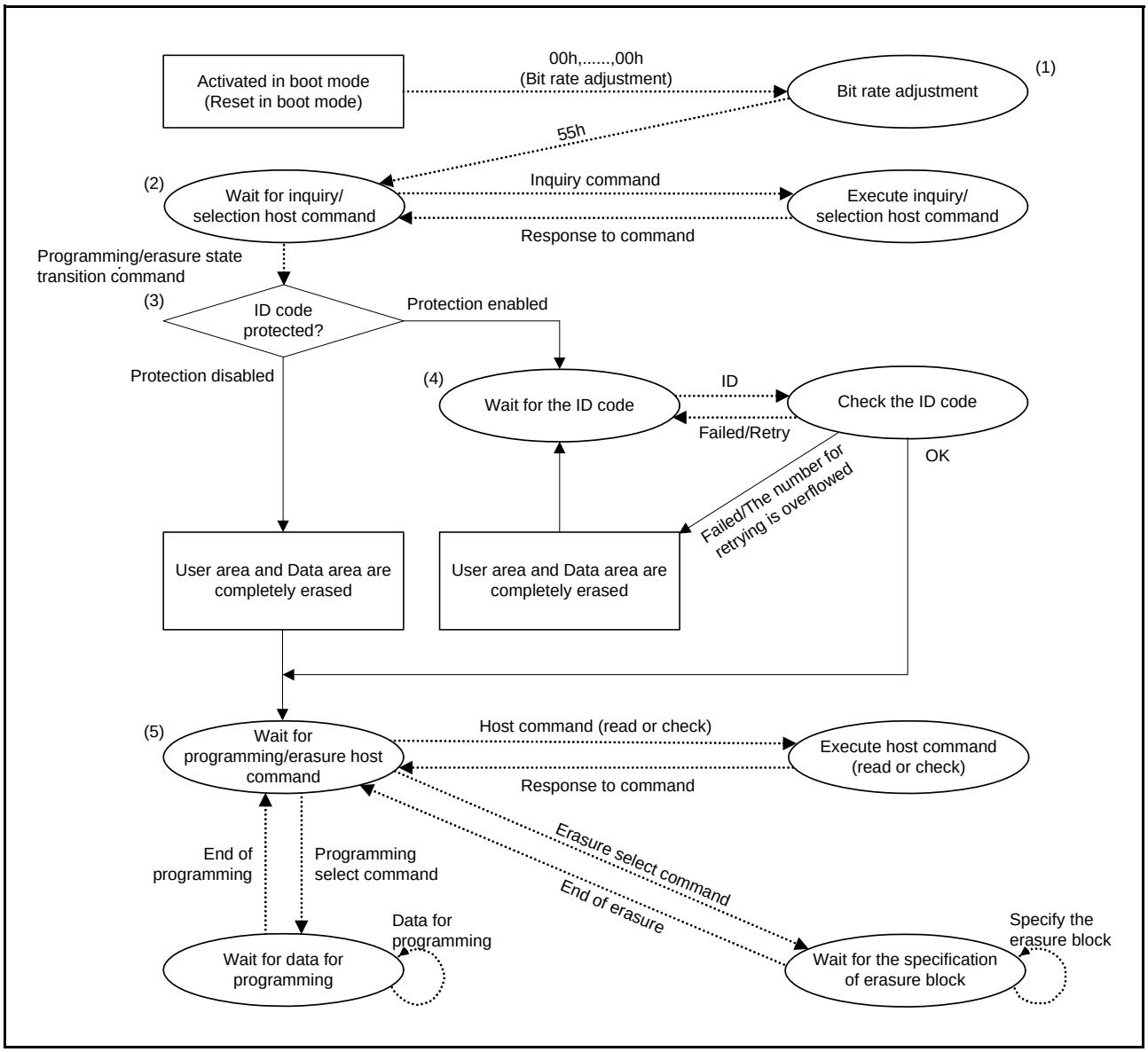


Figure 31.26 State Transitions in Boot Mode

(1) Matching the Bit Rates

When the RX62T is activated in boot mode, the bit rate of the SCI is automatically adjusted to match that of the host. On completion of this adjustment, the RX62T transmits the value 00h to the host. On subsequent correct reception of the value 55h sent from the host, the RX62T enters the state of waiting for a host command for inquiry or selection. For details on matching of the bit rates, see section 31.9.4, Automatic Adjustment of the Bit Rate.

(2) Waiting for a Host Command for Inquiry or Selection

This state is for inquiries on area size, area configuration, the addresses where areas start, the state of support etc., and for selection of the device, clock mode, and bit rate. The RX62T receives a programming/erasure state transition command issued by the host and then enters the state to determine whether ID code protection is enabled or disabled. For the inquiry/selection host commands, see section 31.9.5, Inquiry/Selection Host Command Wait State.

(3) Judging ID Code Protection

This state is for determining whether ID code protection is enabled or disabled. The control code and ID code written in the ROM are used to determine whether ID code protection is enabled or disabled. When enabled, the state of waiting for the ID code is entered. When disabled, the user area and data area are all completely erased, and the state of waiting for programming and erasure commands from the host is entered. For details on the control code and ID code, see section 31.9.2, ID Code Protection.

(4) Waiting for an ID Code

This state is for waiting for the control code and ID code to be sent from the host. The control code and ID code sent by the host are compared with the code stored in the ROM, and the state of waiting for programming and erasure commands from the host is entered if the two match. If they do not match, the next transition is back to the state of waiting for an ID code. However, if the ID codes fail to match three times in a row and also the state of protection is authentication method 1, the ROM is completely erased, and the state of waiting for an ID code is entered again. A reset is required to release the system from this state due to non-matching ID codes. For details on the control code and ID code, see section 31.9.2, ID Code Protection.

(5) Waiting for a Host Command for Programming or Erasure

In this state, programming and erasure proceed in accordance with commands from the host. In response to the reception of a command, the RX62T enters the state of waiting for the data to use in programming, waiting for specification of the erasure block to be erased, or executing the processing of commands for reading, fetching and so on.
When the RX62T receives a programming selection command, it enters the state of waiting for the data to use in programming. After the host has issued the programming selection command, the process continues with the address where programming is to start and then the data for programming. Setting of FFFF FFFFh as the address where programming is to start indicates the completion of programming, and the next transition is from the state of waiting for the data to use in programming to the state of waiting for programming and erasure commands.
When the RX62T receives a programming selection command, it enters the state of waiting for specification of the erasure block to be erased. After the host has issued the programming selection command, the process continues with the number of the erasure block to be erased. Setting of FFh as the number of the erasure block indicates the completion of erasure, and the next transition is from the state of waiting for specification of the erasure block to the state of waiting for programming and erasure commands. Since the user area and data area are all completely erased during the interval between booting up in boot mode and transition to the state of waiting for programming and erasure commands, explicit execution of erasure is not necessary unless newly programmed data are to be erased without a further reset.
Other than the programming and erasure commands, commands from the host for execution in this state include those for sum checking of the user area, blank checking (to confirm erasure), reading from memory, and acquiring state information.

31.9.4 Automatic Adjustment of the Bit Rate

When the RX62T is booted up in boot mode, asynchronous transfer by the SCI is used to measure the periods at low level of consecutive bytes with value 00h that are sent from the host. While the period at low level is being measured, set the host's SCI parameters to eight-bit data, one stop bit, no parity, and a transfer rate of 9,600 bps or 19,200 bps. The RX62T calculates the host's SCI bit rate from the measured periods at low level, adjusts its own bit rate accordingly, and then sends a 00h byte to the host. If reception of the value 00h by the host is normal, the host responds by sending the value 55h to the RX62T. If normal reception of 00h by the host is not possible, the RX62T is re-booted in boot mode, and then repeats the process of automatically adjusting the bit rate. If reception of the value 55h by the RX62T is normal, it responds by sending E6h to the host, and if normal reception of 55h by the RX62T is not possible, it responds by sending FFh to the host.

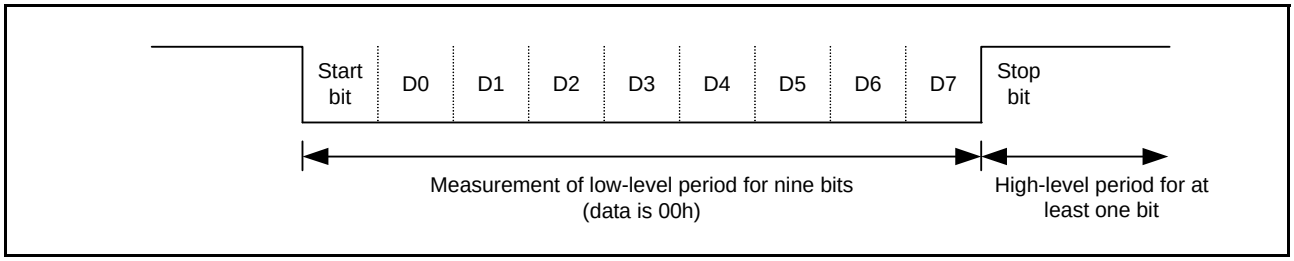


Figure 31.27 Transfer Format Used by the SCI in Automatic Adjustment of the Bit Rate

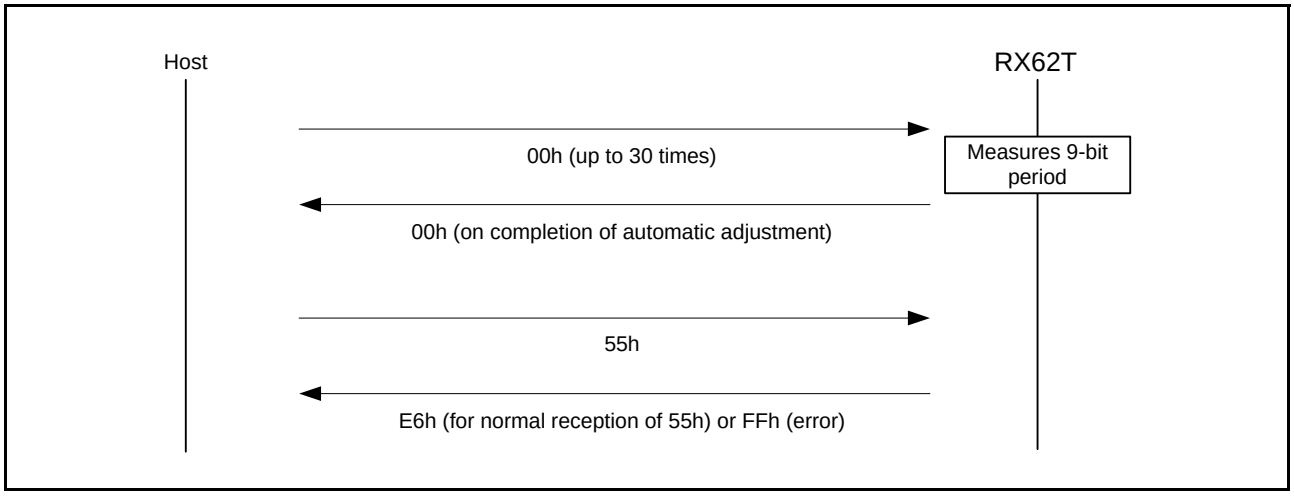


Figure 31.28 Sequence of Transfer between the Host and RX62T

Since the bit rate of the RX62T's SCI module depends on the frequency of the peripheral clock, adjustment to match the bit rate of the host will not be possible under some conditions. Accordingly, ensure that SCI transfer is under the conditions given in Table 31.11.

Table 31.11 Conditions for Automatic Bit-Rate Adjustment to be Possible

Bit Rate of the SCI in the Host	Range of Frequency for the EXTAL Signal
9,600 bps	8 to 14 MHz
19,200 bps	8 to 14 MHz

31.9.5 Inquiry/Selection Host Command Wait State

Table 31.12 shows the host commands available in the inquiry/selection host command wait state. The embedded program status inquiry command can also be used in the programming/erasure host command wait state. The other commands can only be used in the inquiry/selection host command wait state.

Table 31.12 Inquiry/Selection Host Commands

Host Command Name	Function
Supported device inquiry	Inquires regarding the device codes and the product codes for the embedded programs
Device selection	Selects a device code
Clock mode inquiry	Inquires regarding the clock mode
Clock mode selection	Notifies the selected clock mode
Multiplication ratio inquiry	Inquires regarding the number of clock types, the number of multiplication/division ratios, and the multiplication /division ratios
Operating frequency inquiry	Inquires regarding the number of clock types and the maximum and minimum operating frequencies
User area information inquiry	Inquires regarding the number of user areas and the start and end addresses
Erasure block information inquiry	Inquires regarding the number of blocks and the start and end addresses
Programming size inquiry	Inquires regarding the size of programming data
New bit rate selection	Modifies the bit rate of SCI communications between the host and RX62T
Programming/erasure state transition	Enters the state for determining ID code protection
Embedded program status inquiry	Inquires regarding the processing state

If the host has sent an undefined command, the RX62T returns a response indicating a command error in the format shown below. The command field holds the first byte of the undefined command sent from the host.

Error response	80h	Command

In the inquiry/selection host command wait state, send selection commands from the host in the order of device selection, clock mode selection, and new bit rate selection to set up the RX62T according to the responses to inquiry commands.

that the supported device inquiry and clock mode inquiry commands are the only inquiry commands that can be sent before the clock mode selection command; other inquiry commands must not be issued before the clock mode selection command. If commands are issued in an incorrect order, the RX62T returns a response indicating a command error. Figure 31.29 shows an example of the procedure to use inquiry/selection host commands.

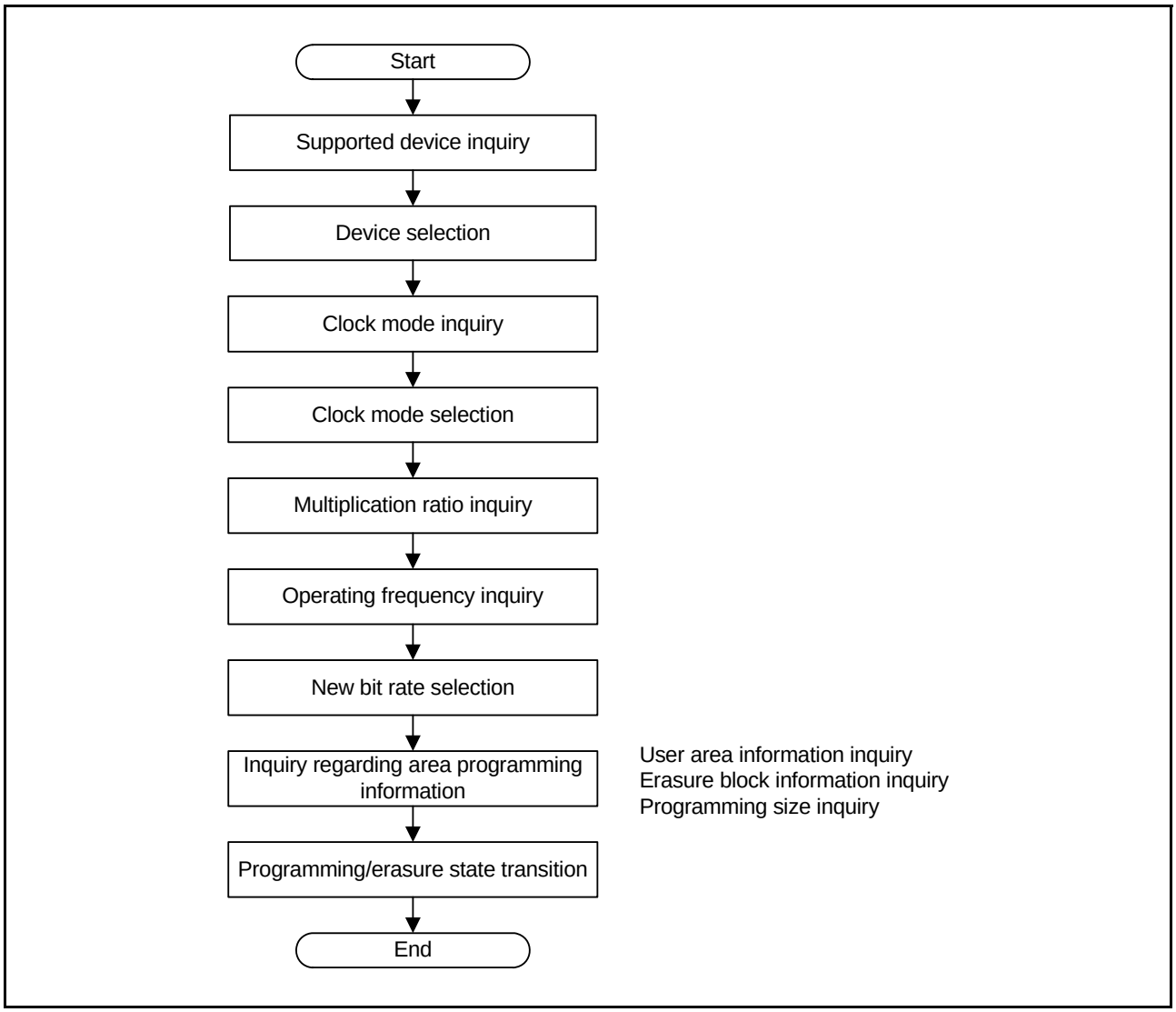


Figure 31.29 Example of Procedure to Use Inquiry/Selection Host Commands for User Area

Each host command is described in detail below. The "command" in the description indicates a command sent from the host to the RX62T and the "response" indicates a response sent from the RX62T to the host. The "checksum" is byte-size data calculated so that the sum of all bytes to be sent by the RX62T becomes 00h.

(1) Supported Device Inquiry

In response to a supported device inquiry command sent from the host, the RX62T returns the information concerning the devices supported by the embedded program for boot mode. If the supported device inquiry command comes after the host has selected a device, the RX62T only returns the information concerning the selected device.

Command	20h		

Response	30h	Size	Device count	
	Character count	Device code		Product code
	Character count	Device code		Product code
	:	:		:
	Character count	Device code		Product code
	SUM			

Size (1 byte): Total number of bytes in the device count, character count, device code, and product code fields}
Device count (1 byte): Number of device types supported by the embedded program for boot mode
Character count (1 byte): Number of characters included in the device code and product code fields
Device code (4 bytes): ASCII code for the product name of the chip
Product code (n bytes): ASCII code for the supported device
SUM (1 byte): Checksum (in response)

(2) Device Selection

In response to a device selection command sent from the host, the R RX62T checks if the selected device is supported. When the selected device is supported, the RX62T specifies this device as the device for use and returns a response (06h). If the selected device is not supported or the sent command is illegal, the RX62T returns an error response (90h). Even when 01h has been returned as the number of supported devices in response to a supported device inquiry command, issue a device selection command to specify the device code that has been returned as the result of the inquiry.

Command	10h	Size	Device code	SUM

Response	06h

Error response	90h	Error

Size (1 byte): Number of characters in the device code field (fixed at four)
Device code (4 bytes): ASCII code for the product name of the chip (one of the device codes returned in response to the supported device inquiry command)
SUM (1 byte): Checksum
Error (1 byte): Error code
11h: Checksum error (illegal command)
21h: Incorrect device code error

(3) Clock Mode Inquiry

In response to a clock mode inquiry command sent from the host, the RX62T returns the supported clock modes. If the clock mode inquiry command comes after the host has selected a clock mode, the RX62T only returns the information concerning the selected clock mode.

Command	21h			
Response	31h	Size		
	Mode	Mode	. . .	Mode
	SUM			

Size (1 byte): Total number of bytes in the mode count and mode fields
Mode (1 byte): Supported clock mode (for example, 01h indicates clock mode 1)
SUM (1 byte): Checksum

(4) Clock Mode Selection

In response to a clock mode selection command sent from the host, the RX62T checks if the selected clock mode is supported. When the selected mode is supported, the RX62T specifies this clock mode for use and returns a response (06h). If the selected mode is not supported or the sent command is illegal, the RX62T returns an error response (91h). Be sure to issue a clock mode selection command only after issuing a device selection command. Even when 00h or 01h has been returned as the number of supported clock modes in response to a clock mode inquiry command, issue a clock mode selection command to specify the clock mode that has been returned as the result of the inquiry.

Command	11h	Size	Mode	SUM
Response	06h			
Error response	91h	Error		

Size (1 byte): Number of characters in the mode field (fixed at 1)
Mode (1 byte): Clock mode (same mode as the response to the clock mode inquiry command)
SUM (1 byte): Checksum
Error (1 byte): Error code
11h: Checksum error (illegal command)
21h: Incorrect clock mode error

(5) Multiplication Ratio Inquiry

In response to a multiplication ratio inquiry command sent from the host, the RX62T returns the clock types, the number of multiplication/division ratios, and the multiplication division ratios supported.

Command

22h

Response

32h	Size	Clock type count		
Multiplication ratio count	Multiplication ratio	Multiplication ratio	. . .	Multiplication ratio
Multiplication ratio count	Multiplication ratio	Multiplication ratio	. . .	Multiplication ratio
:	:	:	. . .	:
Multiplication ratio count	Multiplication ratio	Multiplication ratio	. . .	Multiplication ratio
SUM				

Size (1 byte): Total number of bytes in the clock type count, multiplication ratio type, and multiplication ratio fields

Clock type count (1 byte): Number of clock types (for example, 02h indicates two clock types; that is, a system clock and a peripheral clock)

Multiplication ratio count (1 byte): Number of supported multiplication/division ratios (for example, 04h indicates that four multiplication ratios are supported for the system clock (x1, x2, x4, and x8))

Multiplication ratio (1 byte): A positive value indicates a multiplication ratio (for example, 04h = 4 = multiplication by 4)
A negative value indicates a division ratio (for example, FEh = -2 = division by 2)

SUM (1 byte): Checksum

(6) Operating Clock Frequency Inquiry

In response to an operating clock frequency inquiry command sent from the host, the RX62T returns the minimum and maximum frequencies for each clock.

Command

23h

Response

33h	Size	Clock type count
Minimum frequency		Maximum frequency
Minimum frequency		Maximum frequency
:		:
Minimum frequency		Maximum frequency
SUM		

Size (1 byte): Total number of bytes in the clock type count, minimum frequency, and maximum frequency fields

Clock type count (1 byte): Number of clock types (for example, 02h indicates two clock types; that is, a system clock and a peripheral clock)

Minimum frequency (2 bytes): Minimum value of the operating frequency (for example, 07D0h indicates 20.00 MHz). This value should be calculated by multiplying the frequency value (MHz) to two decimal places by 100.

Maximum frequency (2 bytes): Maximum value of the operating frequency represented in the same format as the minimum frequency

SUM (1 byte): Checksum

(7) User Area Information Inquiry

In response to a user area information inquiry command sent from the host, the RX62T returns the number of user area areas and their addresses.

Command 25h

Response

35h	Size	Area count
Area start address		
Area end address		
Area start address		
Area end address		
:		
Area start address		
Area end address		
SUM		

Size (1 byte): Total number of bytes in the area count, area start address, and area end address fields

Area count (1 byte): Number of user area areas (consecutive areas are counted as one area)

Area start address (4 bytes): Start address of a user area

Area end address (4 bytes): End address of a user area

SUM (1 byte): Checksum

(8) Erasure Block Information Inquiry

In response to an erasure block information inquiry command sent from the host, the RX62T returns the number of erasure blocks in the user area and their addresses.

Command	26h

Response	36h	Size	Block count
	Block start address		
	Block end address		
	Block start address		
	Block end address		
	:		
	Block start address		
	Block end address		
	SUM		

Size (2 byte): Total number of bytes in the block count, block start address, and block end address fields
Block count (1 byte): Number of erasure blocks in the user area
Block start address (4 bytes): Start address of an erasure block
Block end address (4 bytes): End address of an erasure block
SUM (1 byte): Checksum

(9) Programming Size Inquiry

In response to a programming size inquiry command sent from the host, the RX62T returns the programming size.

Command	27h

Response	37h	Size	Programming size	SUM

Size (1 byte): Number of characters included in the programming size field (fixed at two)
Programming size (2 bytes): Programming unit (bytes)
SUM (1 byte): Checksum

(10) New Bit Rate Selection

In response to a new bit rate selection command sent from the host, the RX62T checks if the on-chip SCI can be set to the selected new bit rate. When the SCI can be set to the new bit rate, the RX62T returns a response (06h) and sets the SCI to the new bit rate. If the SCI cannot be set to the new bit rate or the sent command is illegal, the RX62T returns an error response (BFh). Upon reception of response 06h, the host waits for a one-bit period in the previous bit rate with which the new bit rate selection command has been sent, and then sets the host's bit rate to the new one. After that, the host sends confirmation data (06h) in the new bit rate, and the RX62T returns a response (06h) to the confirmation data.
Be sure to issue a new bit rate selection command only after a clock mode selection command.

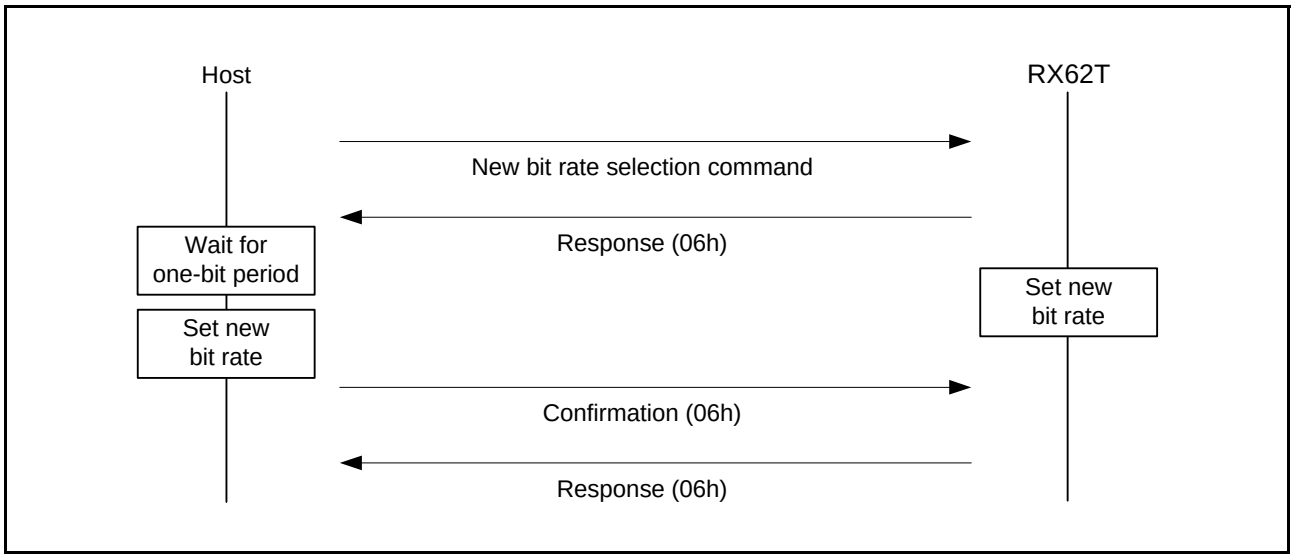


Figure 31.30 New Bit Rate Selection Sequence

Command	3Fh	Size	Bit rate	Input frequency
	Clock type count	Multiplication ratio 1	Multiplication ratio 2	
	SUM			
Response	06h			
Error response	BFh	Error		
Confirmation	06h			
Response	06h			

Size (1 byte):	Total number of bytes in the bit rate, input frequency, clock type count, and multiplication ratio fields
Bit rate (2 bytes):	New bit rate (for example, 00C0h indicates 19200 bps) 1/100 of the new bit rate value should be specified.
Input frequency (2 bytes):	Clock frequency input to the RX62T (for example, 04E2h indicates 12.50 MHz) This value should be calculated by multiplying the input frequency value to two decimal places by100.
Clock type count (1 byte):	Number of clock types (for example, 02h indicates two clock types; that is, a system clock and

	a peripheral clock)
Multiplication ratio 1 (1 byte):	Multiplication/division ratio of the input frequency to obtain the system clock (ICLK) A positive value indicates a multiplication ratio (for example, 04h = 4 = multiplication by 4) A negative value indicates a division ratio (for example, FEh = -2 = division by 2)
Multiplication ratio 2 (1 byte):	Multiplication/division ratio of the input frequency to obtain the peripheral clock (PCLK) This value is represented in the same format as multiplication ratio 1
SUM (1 byte):	Checksum
Error:	Error code 11h: Checksum error 24h: Bit rate selection error 25h: Input frequency error 26h: Multiplication ratio error 27h: Operating frequency error

- Bit rate selection error
  A bit rate selection error occurs when the bit rate selected through a new bit rate selection command cannot be set for the SCI of the RX62T within an error of 4%. The bit rate error can be obtained by the following equation from the bit rate (B) selected through a new bit rate selection command, the input frequency (f_{EX}), multiplication ratio 2 ($M_{P\phi}$), the bit rate register (BRR) setting (N) in the SCI, and the CKS[1:0] bit value (n) in the serial mode register (SMR).

$$\text{Error (\%)} = \frac{f_{EX} \times M_{P\phi} \times 10^6}{(N+1) \times B \times 64 \times 2^{2n-1}} - 1$$

- Input frequency error
  An input frequency error occurs when the input frequency specified through a new bit rate selection command is outside the range from the minimum to maximum input frequencies for the clock mode selected through a clock mode selection command.
- Multiplication ratio error
  A multiplication ratio error occurs when the multiplication ratio specified through a new bit rate selection command does not match the clock mode selected through a clock mode selection command. To check the selectable multiplication ratios, issue a multiplication ratio inquiry command.
- Operating frequency error
  An operating frequency error occurs when the RX62T cannot operate at the operating frequencies selected through a new bit rate selection command. The RX62T calculates the operating frequencies from the input frequency and multiplication ratios specified through a new bit rate selection command and checks if each calculated frequency is within the range from the minimum to maximum frequencies for the respective clock. To check the minimum and maximum operating frequencies for each clock, issue an operating clock frequency inquiry command.

(11) Programming/Erasure State Transition

In response to a programming/erasure state transition command sent from the host, the RX62T determines whether ID code protection is enabled or disabled using the control code and ID code written in the ROM. When ID code protection is enabled, the RX62T returns a response (26h) and waits for the ID code. When ID code protection is disabled, the RX62T erases the entire area of each of the user area and data area. After completing erasure, the RX62T returns a response (06h) and waits for a programming/erasure host command. If the RX62T has failed to complete erasure due to an error, it returns an error response (sends C0h and 51h in that order).
Do not issue a programming/erasure state transition command before device selection, clock mode selection, and new bit rate selection commands.

Command	40h	
Response	ACK	
Error response	C0h	51h

ACK (1 byte): ACK code
06h: ID code protection is disabled
26h: ID code protection is enabled

(12) Embedded Program Status Inquiry

In response to an embedded program status inquiry command sent from the host, the RX62T returns its current status. The embedded program status inquiry command can be issued in both the inquiry/selection host command wait state and programming/erasure host command wait state.

Command	4Fh			
Response	5Fh	Size	Status	Error

Size (1 byte): Total number of bytes in the status and error fields (fixed at two)
Status (1 byte): Current status in the RX62T (see Table 31.13)
Error (1 byte): Error status in the RX62T (see Table 31.14)

Table 31.13 Status Code

Code	Description
11h	Waiting for device selection
12h	Waiting for clock mode selection
13h	Waiting for bit rate selection
1Fh	Waiting for transition to programming/erasure host command wait state (bit rate has been selected)
31h	Erasing the user area
3Fh	Waiting for a programming/erasure host command
4Fh	Waiting for reception of programming data
5Fh	Waiting for erasure block selection

Table 31.14 Error Code

Code	Description
00h	No error
11h	Checksum error
21h	Incorrect device code error
22h	Incorrect clock mode error
24h	Bit rate selection error
25h	Input frequency error
26h	Multiplication ratio error
27h	Operating frequency error
29h	Block number error
2Ah	Address error
2Bh	Data size error
51h	Erasure error
52h	Incomplete erasure error
53h	Programming error
54h	Selection error
80h	Command error
FFh	Bit rate adjustment verification error

31.9.6 ID Code Wait State

Table 31.15 shows the host command available in the ID code wait state.

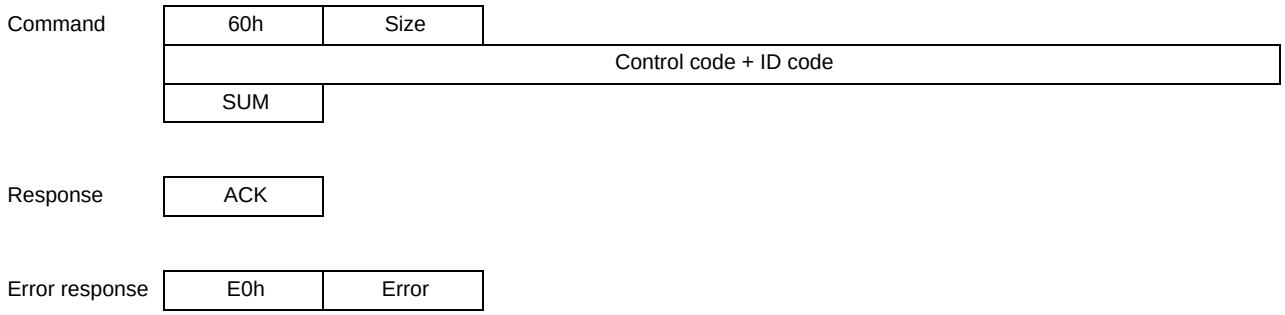
Table 31.15 ID Code Check Host Command

Host Command Name	Function
ID code check	Performs the ID code check

If the host has sent an undefined command, the RX62T returns a response indicating a command error. For the format of this response, see section 31.9.5, Inquiry/Selection Host Command Wait State.

(1) ID Code Check

In response to an ID code check command sent from the host, the RX62T compares the code sent from the host with the control code and ID code in the ROM and returns the result.



Size (1 byte): Number of bytes in the ID code field (fixed at 16)
ID code (16 bytes): Control code (1 byte) + ID code (15 bytes)
SUM (1 byte): Checksum
ACK (1 byte): ACK code
26h: Returns the response for a programming/erasure state transition command
Error (1 byte): Error code
11h: Checksum error
61h: ID code mismatch
63h: ID code mismatch (erasure error)
An error has occurred during erasure triggered by an ID code mismatch.

31.9.7 Programming/Erasure Host Command Wait State

Table 31.16 shows the host commands available in the programming/erasure host command wait state.

Table 31.16 Programming/Erasure Host Commands

Host Command Name	Function
User area programming selection	Selects the program for user area programming
256-byte programming	Programs 256 bytes of data
Erasure selection	Selects the erasure program
Block erasure	Erases block data
Memory read	Reads data from memory
User area checksum	Performs checksum verification for the user area
User area blank check	Checks whether the user area is blank
Read lock bit status	Reads from the lock bit
Lock bit program	Writes to the lock bit
Lock bit enable	Enables the lock bit protection
Lock bit disable	Disables the lock bit protection
Embedded program status inquiry	Inquires regarding the state of the RX62T

If the host has sent an undefined command, the RX62T returns a response indicating a command error. For the format of this response, see section 31.9.5, Inquiry/Selection Host Command Wait State.

To program the ROM, issue a programming selection command (user area programming selection) and then a 256-byte programming command from the host. Upon reception of a programming selection command, the RX62T enters the programming data wait state (see section 31.9.3, State Transitions in Boot Mode). In response to a 256-byte programming command sent from the host in this state, the RX62T starts programming the ROM. When the host sends a 256-byte programming command specifying FFFF FFFFh as the programming start address, the RX62T detects it as the end of programming and enters the programming/erasure host command wait state.

To erase the ROM, issue an erasure selection command and then a block erasure command from the host. Upon reception of an erasure selection command, the RX62T enters the erasure block selection wait state (see section 31.9.3, State Transitions in Boot Mode). In response to a block erasure command sent from the host in this state, the RX62T erases the specified block in the ROM. When the host sends a block erasure command specifying FFh as the block number, the RX62T detects it as the end of erasure and enters the programming/erasure host command wait state.

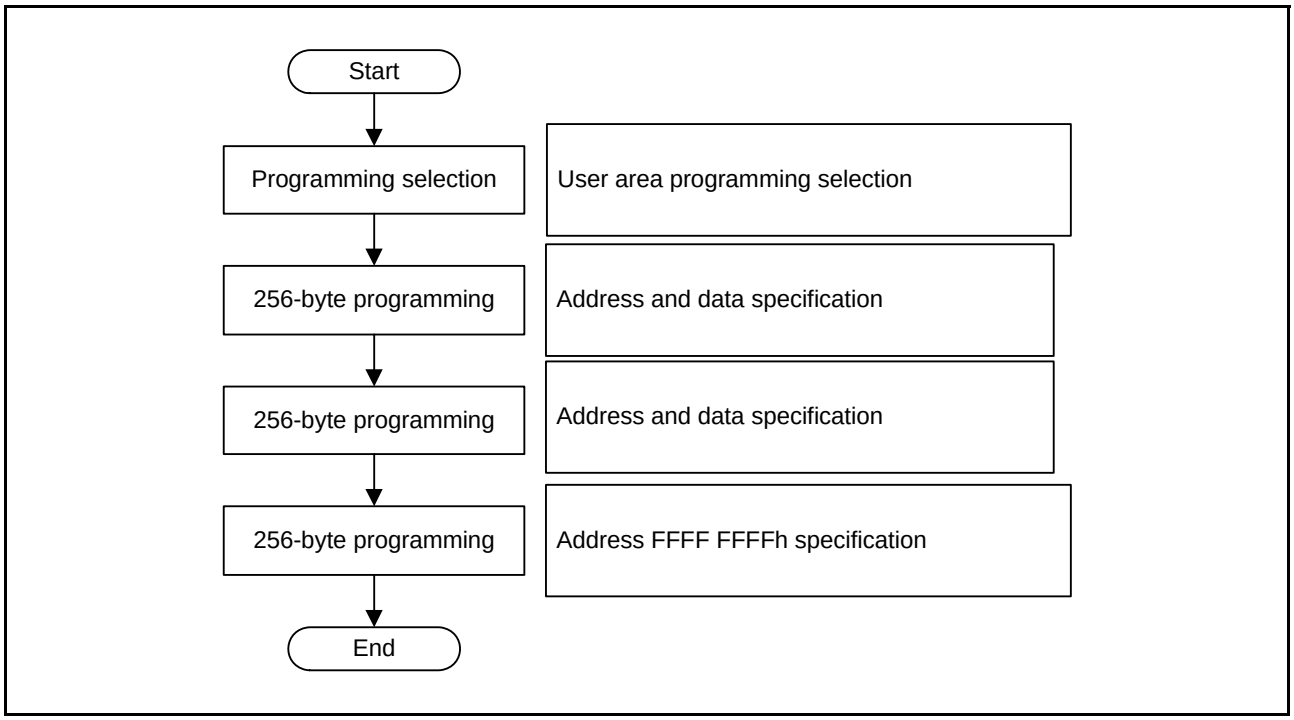


Figure 31.31 Procedure for ROM Programming in Boot Mode

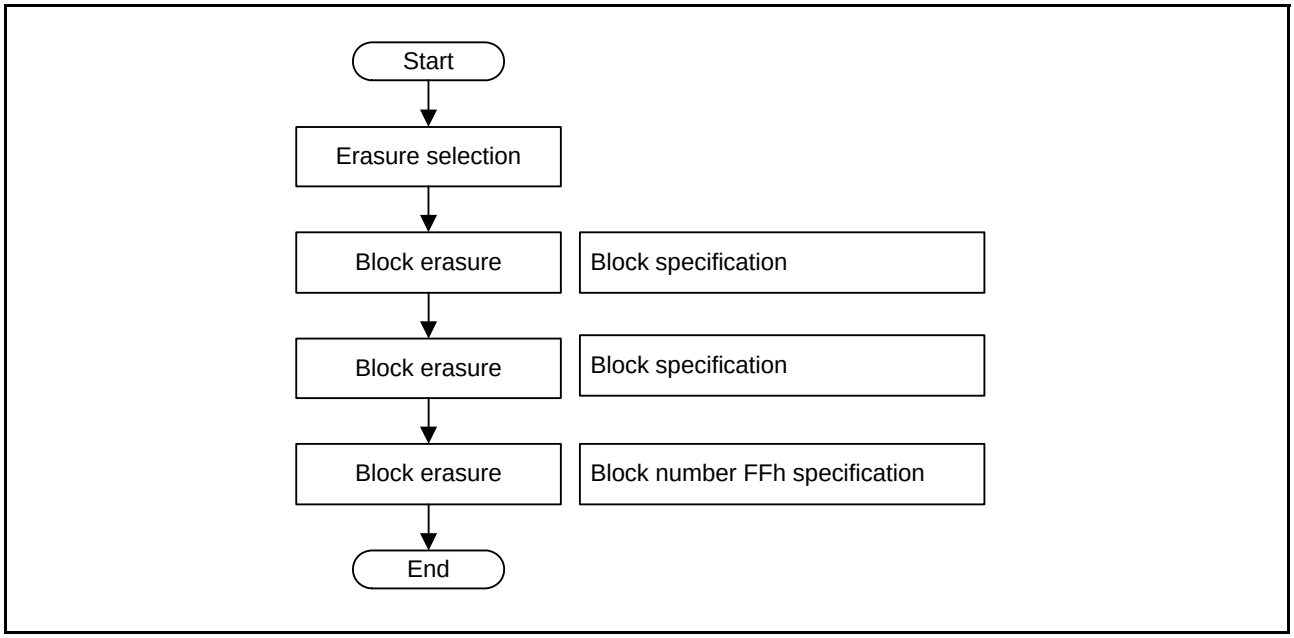


Figure 31.32 Procedure for ROM Erasure in Boot Mode

Each host command is described in detail below. The "command" in the description indicates a command sent from the host to the RX62T and the "response" indicates a response sent from the RX62T to the host. The "checksum" is byte-size data calculated so that the sum of all bytes to be sent by the RX62T becomes 00h.

(1) User Area Programming Selection

In response to a user area programming selection command sent from the host, the RX62T selects the program for user area programming and waits for programming data.

Command	43h
Response	06h

(2) 256-Byte Programming

In response to a 256-byte programming command sent from the host, the RX62T programs the ROM. After completing ROM programming successfully, the RX62T returns a response (06h). If an error has occurred during ROM programming, the RX62T returns an error response (D0h).

Command	50h	Programming address		
	Data	Data	. . .	Data
	SUM			
Response	06h			
Error response	D0h	Error		

Programming address (4 bytes): Target address of programming
To program the ROM, a 256-byte boundary address should be specified.
To terminate programming, FFFF FFFFh should be specified.

Data (256 bytes): Programming data
FFh should be specified for the bytes that do not need to be programmed.
When terminating programming, no data needs to be sent
(only the programming address and SUM should be sent in that order).

SUM (1 byte): Checksum

Error (1 byte): Error code
11h: Checksum error
2Ah: Address error (the specified address is not in the target area)
53h: Programming cannot be done due to a programming error

(3) Erasure Selection

In response to an erasure selection command sent from the host, the RX62T selects the erasure program and waits for erasure block specification.

Command	48h
Response	06h

(4) Block Erasure

In response to a block erasure command sent from the host, the RX62T erases the ROM. After completing ROM erasure successfully, the RX62T returns a response (06h). If an error has occurred during ROM erasure, the RX62T returns an error response (D8h).

Command	58h	Size	Block	SUM
Response	06h			
Error response	D8h	Error		

Size (1 byte): Number of bytes in the block specification field (fixed at 1)
Block (1 byte): Block number whose data is to be erased
To terminate erasure, FFh should be specified.
SUM (1 byte): Checksum
Error (1 byte): Error code
11h: Checksum error
29h: Block number error (an incorrect block number is specified)
51h: Erasure cannot be done due to an erasure error

(5) Memory Read

In response to a memory read command sent from the host, the RX62T reads data from the ROM. After completing ROM reading successfully, the RX62T returns the data stored in the address specified by the memory read command. If the RX62T has failed to read the ROM, the RX62T returns an error response (D2h).

Command	52h	Size	Area	Read start address	
	Reading size			SUM	
Response	52h	Reading size			
	Data	Data	. . .	Data	
	SUM				
Error response	D2h	Error			

Size (1 byte): Total number of bytes in the area, read start address, and reading size fields
Area (1 byte): Target area to be read
01h: User area
Read start address (4 bytes): Start address of the area to be read
Reading size (4 bytes): Size of data to be read (bytes)
SUM (1 byte): Checksum
Data (1 byte): Data read from the ROM
Error (1 byte): Error code
11h: Checksum error
2Ah: Address error
- The value specified for area selection is neither 00h nor 01h.
- The specified read start address is outside the selected area.

2Bh: Data size error
- 00h is specified for the reading size.

- The reading size is larger than the area.
- The end address calculated from the read start address and the reading size is outside the selected area.

(6) User Area Checksum

In response to a user area checksum command sent from the host, the RX62T sums the user area data in byte units and returns the result (checksum).

Command	4Bh			
Response	5Bh	Size	Area checksum	SUM

Size (1 byte): Number of bytes in the area checksum field (fixed at 4)
Area checksum (4 bytes): Checksum of the user area data
The user area also stores the key code for debugging function authentication. Note that the checksum includes this key code value.
SUM (1 byte): Checksum (for the response data)

(7) User Area Blank Check

In response to a user area blank check command sent from the host, the RX62T checks whether the user area is completely erased. When the use area is completely erased, the RX62T returns a response (06h). If the user area has an unerased area, the RX62T returns an error response (sends CDh and 52h in that order).

Command	4Dh	
Response	06h	
Error response	CDh	52h

(8) Read Lock Bit Status

In response to a read lock bit status command sent from the host, the RX62T reads data from the lock bit. After completing the lock bit reading successfully, the RX62T returns the data stored in the address specified by the read lock bit status command. If the RX62T has failed to read the lock bit, the RX62T returns an error response (F1h).

Command	71h	Size	Area	Third highest order address	Second highest order address	Highest order address	SUM
Response	Status						
Error response	F1h	Error					

Size (1 byte): Total number of bytes in the area, third highest order address, second highest order address, and highest order address fields (fixed at 4 in the RX62T)

Area (1 byte): Target area to be read
01h: User area

Third highest order address (1 byte): Third highest order address at the specified block's end address (8 to 15 bits)

Second highest order address (1 byte): Second highest order address at the specified block's end address (16 to 23 bits)

Highest order address (1 byte): Highest order address at the specified block's end address (24 to 31 bits)

SUM (1 byte): Checksum

Status (1 byte): Bit 6 locked at "0"
Bit 6 unlocked at "1"

Error (1 byte): Error code
11h: Checksum error
2Ah: Address error (the specified address is not in the target area)

(9) Lock Bit Program

In response to a lock bit program command sent from the host, the RX62T writes to a lock bit and locks the specified block. After completing the lock bit blocking successfully, the RX62T returns a response (06h). If the RX62T has failed to lock, the RX62T returns an error response (F7h).

Command	77h	Size	Area	Third highest order address	Second highest order address	Highest order address	SUM

Response	06h

Error response	F7h	Error

Size (1 byte): Total number of bytes in the area, third highest order address, second highest order address, and highest order address fields (fixed at 4 in the RX62T)

Area (1 byte): Target area to be locked
01h: User area

Third highest order address (1 byte): Third highest order address at the specified block's end address (8 to 15 bits)

Second highest order address (1 byte): Second highest order address at the specified block's end address (16 to 23 bits)

Highest order address (1 byte): Highest order address at the specified block's end address (24 to 31 bits)

SUM (1 byte): Checksum

Error (1 byte): Error code
11h: Checksum error
2Ah: Address error (the specified address is not in the target area)
53h: Locking cannot be done due to a programming error

(10) Lock Bit Enable

In response to a lock bit enable command sent from the host, the RX62T enables a lock bit.

Command	7Ah

Response	06h

(11) Lock Bit Disable

In response to a lock bit disable command sent from the host, the RX62T disables a lock bit.

Command	75h

Response	06h

(12) Embedded Program Status Inquiry

For details, refer to section 31.9.5, Inquiry/Selection Host Command Wait State.

31.10 ID Code Protection on Connection of the On-Chip Debugger

This function is used to prohibit connection with the on-chip debugger. When connecting an on-chip debugger, the control code and ID code that have been written to the ROM are used to determine whether ID code protection on connection of the on-chip debugger is enabled or disabled and to judge ID code protection on connection of the on-chip debugger. When the ID code protection is enabled, the code sent from the on-chip debugger is compared with the control code and ID code in the ROM to determine whether they match. If they match, connection with the on-chip debugger is allowed. If they do not match, the on-chip debugger cannot be connected. However, if the control code is 52h and the ID code is 50h, 72h, 6Fh, 74h, 65h, 63h, 74h, FFh, ..., FFh (from the ID code 1 field), there is no determination of matching and the ID code is always considered to be non-matching. Furthermore, if all bytes of the control code and ID code have the value FFh, there is no determination of matching, the ID code is always considered to match, and connection of the on-chip debugger is allowed. See Figure 31.25 for the configuration of ID codes in flash memory.

Table 31.17 Specifications for ID Code Protection on Connection of the On-Chip Debugger

Table 31.17 Specifications for ID Code Protection on Connection of the On-Chip Debugger

Control Code	ID Code	State of Protection	Operations at the Time of Connection with the On-Chip Debugger
FFh	FFh, …, FFh (all bytes FFh)	Protection disabled	The control code and ID code are not judged, the ID code always matches, and connection to the on-chip debugger is permitted.
52h	50h, 72h, 6Fh, 74h, 65h, 63h, 74h, FFh, ..., FFh	Protection enabled	The control code and ID code are not judged, the ID code is always non-matching, and connection to the on-chip debugger is prohibited.
Other than the above	Other than the above	Protection enabled	Matching ID code: Authentication of the on-chip debugger is ended and connection with the on-chip debugger is permitted. Non-matching ID code: Further transition to the ID code protection waiting state

31.11 ROM Code Protection

ROM code protection is a facility for prohibiting a PROM programmer from reading from or writing to flash memory. The ROM code in flash memory is a 32-bit code. Figure 31.33 shows the configuration of ROM codes. Set ROM codes as 32-bit units.
For release from ROM code protection, erase block EB00 (erasure block 00) in boot mode or by user programming.

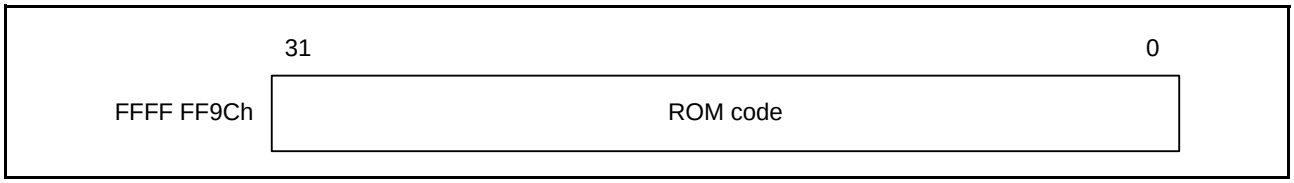


Figure 31.33 Configuration of a ROM Code

Table 31.18 Specifications for ROM Code Protection

ROM Code	State of Protection	Operations at the Time of Connection with the PROM Programmer
0000 0000h	Protection enabled (ROM code protection 1)	Access (both reading and writing) to the user area is prohibited.
0000 0001h	Protection enabled (ROM code protection 2)	Reading from the user area is prohibited.
Other than the above	Protection disabled	Access (both reading and writing) to the user area is permitted.

31.12 Usage Notes

(1) Areas where Programming or Erasure is Suspended

Data in areas where programming or erasure is suspended are undefined. To avoid malfunctions due to the reading of undefined data, prevent the reading of data and execution of code from areas where programming or erasure is currently suspended.

(2) Suspending Programming or Erasure

If you use the programming/erasure suspension command to suspend the processing of programming or erasure, be sure to use the resumption command so that the processing is completed. Within 20 µs (PCLK = 50 MHz) after the resume command has been issued, do not issue the programming/erasing suspension command again.

(3) Prohibition of Reprogramming

Two or more programming operations cannot be performed for the same address range. If an address range that has already been programmed is to be programmed again, be sure to erase the area in advance of the programming.

(4) Reset during Programming or Erasure

When applying a reset on the RES# pin during programming or erasure, only release the chip from the reset state after at least 100 µs have elapsed while the operating voltage is within the range specified in the electrical characteristics.
When using the FRESETR.FRESET bit to reset the FCU during programming or erasure, make sure that the reset state is maintained over tRESW2 (see section 33, Electrical Characteristics). Do not allow programming or erasure of the ROM while the FCU is being reset.
WDT and IWDT resets during programming or erasure can be used without securing the above intervals.

(5) Prohibition of Non-maskable Interrupts during Programming or Erasure

The generation of a non-maskable interrupt (interrupt on the NMI pin, oscillation-stoppage detected interrupt, or a voltage-monitoring 1 interrupt, or voltage-monitoring 2 interrupt) during programming or erasure leads to fetching of the corresponding vector from the ROM, but the data read out are undefined. Therefore, make sure that non-maskable interrupts are not generated during programming or erasure (this prohibition only applies to the ROM).

(6) Interrupt Vector Assignment During Programming or Erasure

The generation of interrupts during programming or erasure may lead to the fetching of vectors from the ROM. To prevent access to the ROM area due to the generation of interrupts, set the interrupt table register (INTB) of the CPU so that the destination for the fetching of interrupt vector is an area outside the ROM.

(7) Abnormal Termination of Programming and Erasure

When programming or erasure is not completed normally due to a fluctuation of the operating voltage above the allowed range, a reset, a reset of the FCU by using the FRESETR.FRESET bit, entry to the command-locked state due to the detection of an error, or any of the prohibited items listed under point (8) below, the value of the lock bit becomes zero (corresponding to the protected state). In such cases, issue a block-erasure command to erase the lock bit while the FPROTR.FPROTCN bit is 1. After that, repeat the programming that was not completed normally.

(8) Actions Prohibited during Programming and Erasure

To prevent damage to the flash memory during programming or erasure, observe the prohibitions described below.

- In an RX62T product, the voltage from the power supply being beyond the allowed range of operating voltage
- A change to the value of the FWEPROR.FLWE[1:0] bits
- A change to the operating mode due to the setting of the SYSCR0.ROME bit
- A change to the PCLK multiplication ratio due to the setting in the SCKCR register
- Setting the PCKAR register for a frequency other than that of PCLK
- A transition to all-module clock stop mode, software standby mode, or deep software standby mode.

32. Data Flash Memory (Flash Memory for Data Storage)

The RX62T Group has a maximum 256-Kbyte (max.) flash memory for storing program code (ROM) and an 32-Kbyte (max.) flash memory for storing data (data flash).
This section covers the flash memory for data storage. For the ROM, see section 31, ROM (Flash Memory for Code Storage).

32.1 Overview

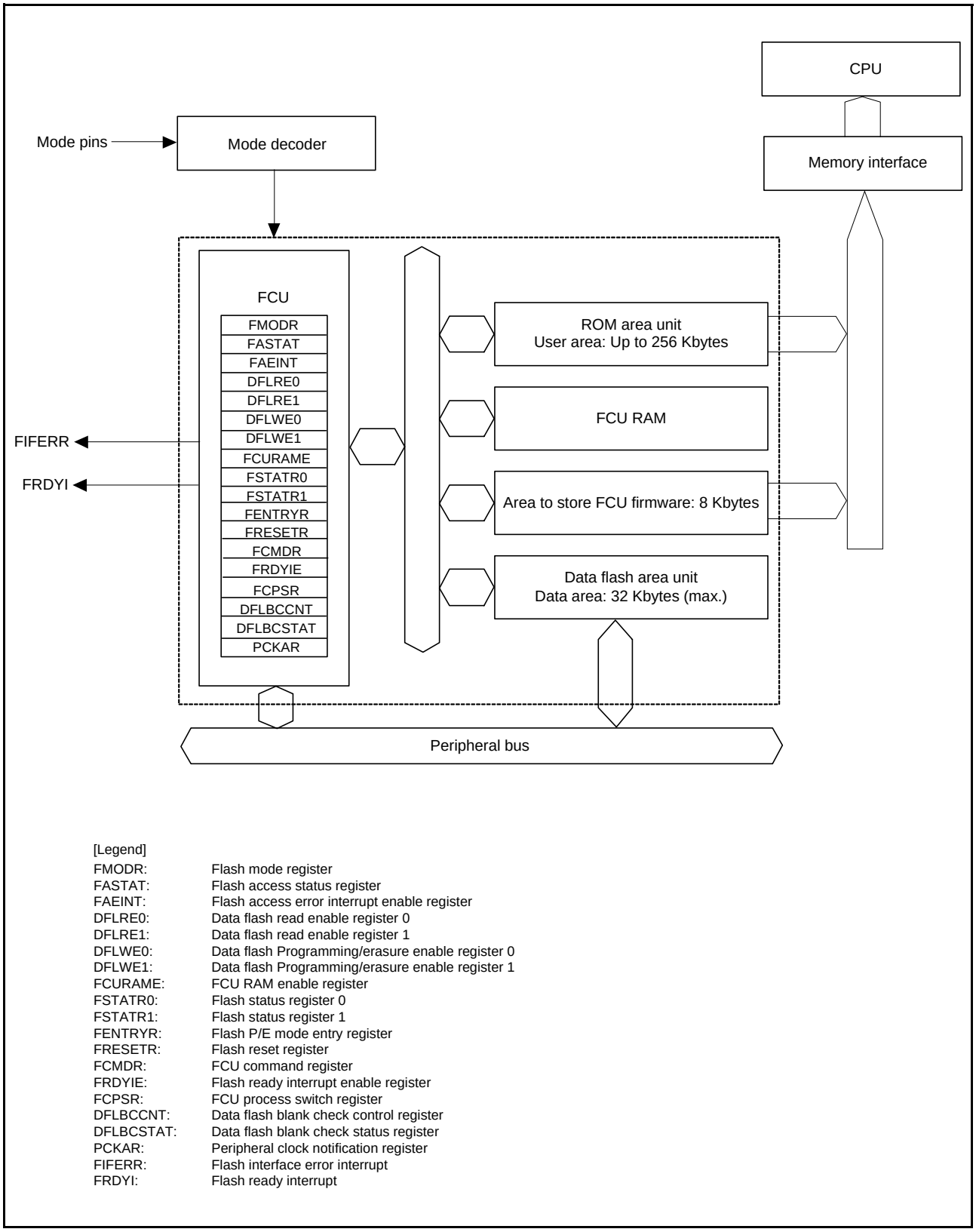
Table 32.1 lists the specifications of the data flash memory, and Figure 32.1 is a block diagram of the ROM, data flash memory, and related modules.

Table 32.1 Specifications of Data Flash Memory

Item		Specifications
Memory capacity		Data area: 32 Kbytes, or 8 Kbytes*1
Reading via the peripheral bus		A read operation takes three cycles of PCLK in words or bytes
Programming/erasing method		• The chip incorporates a dedicated sequencer (FCU) for programming of the data flash. • Programming and erasing the data flash are handled by issuing commands to the FCU.
BGO (background operation)		• The CPU is able to execute program code from areas other than the ROM/data flash while the data flash is being programmed or erased. • Execution of program code from the ROM is possible while the data flash memory is being programmed or erased.
Suspension and resumption		• The CPU is able to read the data flash area by suspending the programming/erasing operation to the data flash (suspended). • Programming and erasure of the ROM can be restarted (resumed) after suspension.
Units of programming and erasure		• Unit of programming for the data area: 8 or 128 bytes • Unit of erasure for the data area: 2 Kbytes (32-Kbyte data flash: 16 blocks 8-Kbyte data flash: 4 blocks)
Blank checking function		• The blank checking command can be executed to check the erasure state of data flash. • The size of the area to be blank-checked is 8 bytes or 2 Kbytes.
On-board programming (two types)		Programming in boot mode • The asynchronous serial interface (SCI1) is used. • The transfer rate is adjusted automatically.
		Programming by a routine for ROM programming within the user program • This allows ROM programming without resetting the system.
Protection	Software-controlled protection	The FENTRYR.FENTRYD bit, FWEPROR.FLWE[1:0] bits, and DFLREk and DFLWEk registers, can be used to prevent unintentional programming. (k = 0, 1)
	Error protection	Prevention of further programming or erasure after the detection of abnormal operations during programming or erasure
Times for programming and erasure, durability (number of times reprogramming is possible)		See section 33, Electrical Characteristics.

Note 1. Each product has different data flash sizes.

Product Code	Data Flash Size	Data Flash Addresses
R5F562TAxxxx	32 Kbytes	0010 0000h to 0010 7FFFh
R5F562T7xxxx	8 Kbytes	0010 0000h to 0010 1FFFh
R5F562T6xxxx		



[Legend]

FMODR:	Flash mode register
FASTAT:	Flash access status register
FAEINT:	Flash access error interrupt enable register
DFLRE0:	Data flash read enable register 0
DFLRE1:	Data flash read enable register 1
DFLWE0:	Data flash Programming/erasure enable register 0
DFLWE1:	Data flash Programming/erasure enable register 1
FCURAME:	FCU RAM enable register
FSTATR0:	Flash status register 0
FSTATR1:	Flash status register 1
FENTRYR:	Flash P/E mode entry register
FRESETR:	Flash reset register
FCMDR:	FCU command register
FRDYIE:	Flash ready interrupt enable register
FCPSR:	FCU process switch register
DFLBCCNT:	Data flash blank check control register
DFLBCSTAT:	Data flash blank check status register
PCKAR:	Peripheral clock notification register
FIFERR:	Flash interface error interrupt
FRDYI:	Flash ready interrupt

Figure 32.1 Block Diagram of Data Flash Memory

Input and output pins associated with the data flash are listed in Table 32.2.

Table 32.2 Input and Output Pins Associated with the Data Flash

Pin Name	I/O	Description
PD5/RxD1	Input	Used in boot mode to receive data via SCI (for host communications)
PD3/TxD1	Output	Used in boot mode to transmit data from SCI (for host communications)
MD1, MD0	Input	Set the operating mode for the RX62T Group

32.2 Register Descriptions

Table 32.3 lists the registers related to the data flash memory. Some registers also have bits related to the ROM, but this section deals only with the bits that are relevant to the data flash. For registers containing bits with common functions for the ROM and data flash (FRDYIE, FCURAME, FSTATR0, FSTATR1, FRESETR, FCMDR, FCPSR, PCKAR, and FWEPROR) and details on the functions of bits dedicated to the ROM, see section 31.2, Register Descriptions in section of ROM (Flash Memory for Code Storage).
The registers related to the data flash are initialized by a reset.

Table 32.3 Registers Related to the Data Flash

Register Name	Symbol	Value after Reset	Address	Access Size
Flash mode register	FMODR	00h	007F C402h	8
Flash access status register	FASTAT	00h	007F C410h	8
Flash access error interrupt enable register	FAEINT	9Bh	007F C411h	8
Flash ready interrupt enable register	FRDYIE	00h	007F C412h	8
Data flash read enable register 0	DFLRE0	0000h	007F C440h	16
Data flash read enable register 1	DFLRE1	0000h	007F C442h	16
Data flash programming/erasure enable register 0	DFLWE0	0000h	007F C450h	16
Data flash programming/erasure enable register 1	DFLWE1	0000h	007F C452h	16
FCU RAM enable register	FCURAME	0000h	007F C454h	16
Flash status register 0	FSTATR0	80h	007F FFB0h	8
Flash status register 1	FSTATR1	00h	007F FFB1h	8
Flash P/E mode entry register	FENTRYR	0000h	007F FFB2h	16
Flash reset register	FRESETR	0000h	007F FFB6h	16
FCU command register	FCMDR	FFFFh	007F FFBAh	16
FCU processing switching register	FCPSR	0000h	007F FFC8h	16
Data flash blank check control register	DFLBCCNT	0000h	007F FFCAh	16
Data flash blank check status register	DFLBCSTAT	0000h	007F FFCEh	16
Peripheral clock notification register	PCKAR	0000h	007F FFE8h	16
Flash write erase protection register	FWEPROR	02h	0008 C289h	8

32.2.1 Flash Mode Register (FMODR)

Address: 007F C402h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	FRDMD	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b3 to b0	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b4	FRDMD	FCU Read Mode Select	0:Memory Area Reading Method The method of lock bit reading is set. Since there are no lock bits for the data flash, undefined data are read from the data flash area after the FCU has been placed in lock bit read mode. 1:Register Reading Method This is the setting when the blank checking command is to be used.	R/W
b7 to b5	—	Reserved	These bits are always read as 0.The write value should always be 0.	R/W

FMODR is used to specify the method for the reading of lock bits. Set the FRDMD bit to 1 if blank checking is to be used.
In modes in which the on-chip ROM is disabled, the value read from FMODR is 00h and writing is disabled.
FMODR is initialized by a reset.

FRDMD Bit (FCU Read Mode Select)

Processing for a transition of the lock bit reading mode is used in processing for blank checking of the data flash.
The FRDMD bit is used to select the method of reading when lock bit values for the ROM are read out (see section 31, ROM (Flash Memory for Code Storage)).

32.2.2 Flash Access Status Register (FASTAT)

Address: 007F C410h

	b7	b6	b5	b4	b3	b2	b1	b0
	ROMAE	—	—	CMDLK	DFLAE	—	DFLRPE	DFLWPE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	DFLWPE	Data Flash Programming/Erasure Protection Violation	0: No data flash programming/erasure command is not issued which conflicts with the DFLWEk settings 1: A data flash programming/erasure command is issued which conflicts with the DFLWEk settings (k = 0, 1)	R/(W)*1
b1	DFLRPE	Data Flash Read Protection Violation	0: There is no such data flash read that conflicts with the DFLREk settings 1: There is such a data flash read that conflicts with the DFLREk settings (k = 0, 1)	R/(W)*1
b2	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b3	DFLAE	Data Flash Access Violation	0: No data flash access violation 1: Data flash access violation	R/(W)*1
b4	CMDLK	FCU Command Lock	0: FCU is not in the command-locked state 1: FCU is in the command-locked state	R
b6, b5	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7	ROMAE	ROM Access Violation	See section 31, ROM (Flash Memory for Code Storage).	R/(W)*1

Note 1. Only 0 can be written after reading 1 to clear the flag.

FASTAT is a register to check if the access to the ROM/data flash is allowed.
When on-chip ROM is disabled, the data read from FASTAT is 00h and writing is disabled. When one of the bits in FASTAT is set to 1, the FCU is placed in the command-locked state (see section 32.7.2, Error Protection). To clear the command-locked state, a status register clearing command must be issued to the FCU after setting FASTAT to 10h.
FASTAT is initialized by a reset.

DFLWPE Bit (Data Flash Programming/Erasure Protection Violation)

This bit is used to indicate whether or not the programming/erasure protection set by DFLWEk (k = 0, 1) is violated.
[Setting condition]

- A programming/erasure command is issued for a data flash area for which programming or erasure is disabled by DFLWEk (k = 0, 1).

[Clearing condition]

- When 0 is written after reading 1

DFLRPE Bit (Data Flash Read Protection Violation)

This bit is used to indicate whether or not the reading protection set by DFLREk (k = 0, 1) is violated.
[Setting condition]

- A read command is issued for a data flash area for which reading is disabled by DFLREk (k = 0, 1).

[Clearing condition]

- When 0 is written after reading 1

DFLAE Bit (Data Flash Read Protection Violation)

This bit indicates whether a data flash access violation occurred.
When the DFLAE bit is set to 1, the ILGLERR bit in FSTATR0 is set to 1, placing the FCU in the command-locked state.
For FSTATR0, see section 32.2.5, Data Flash Read Enable Register 1 (DFLRE1).
[Setting conditions]

- A read command is issued for a data flash area in data flash P/E normal mode and when the FENTRYD bit in FENTRYR is set to 1.
- A write command is issued for a data flash area when the FENTRYD bit is set to 0.
- A command is issued for a data flash area when the FENTRY0 bit in FENTRYR is set to 1.

[Clearing condition]

- When 0 is written after reading 1

CMDLK Bit (FCU Command-Locked)

This command indicates that the FCU is in the command-locked state (see section 32.7.2, Error Protection).
[Setting condition]

- After the FCU detects an error and enters the command-locked state

[Clearing condition]

- After the FCU has processed a status register clearing command

32.2.3 Flash Access Error Interrupt Enable Register (FAEINT)

Address: 007F C411h

	b7	b6	b5	b4	b3	b2	b1	b0
	ROMAEIE	—	—	CMDLKIE	DFLAEIE	—	DFLRPEIE	DFLWPEIE
Value after reset:	1	0	0	1	1	0	1	1

Bit	Symbol	Bit Name	Description	R/W
b0	DFLWPEIE	Data Flash Programming/Erasure Protection Violation Interrupt Enable	0: FIFERR interrupt requests disabled when the DFLWPE bit in FASTAT is set to 1 1: FIFERR interrupt requests enabled when the DFLWPE bit in FASTAT is set to 1	R/W
b1	DFLRPEIE	Data Flash Read Protection Violation Interrupt Enable	0: FIFERR interrupt requests disabled when the DFLRPE bit in FASTAT is set to 1 1: FIFERR interrupt requests enabled when the DFLRPE bit in FASTAT is set to 1	R/W
b2	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b3	DFLAEIE	Data Flash Read Access Violation Interrupt Enable	0: FIFERR interrupt requests disabled when the DFLAE bit in FASTAT is set to 1 1: FIFERR interrupt requests enabled when the DFLAE bit in FASTAT is set to 1	R/W
b4	CMDLKIE	FCU Command Lock Interrupt Enable	0: FIFERR interrupt requests disabled when the CMDLK bit in FASTAT is set to 1 1: FIFERR interrupt requests enabled when the CMDLK bit in FASTAT is set to 1	R/W
b6, b5	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7	ROMAEIE	ROM Access Violation Interrupt Enable	See section 31, ROM (Flash Memory for Code Storage).	R/W

FAEINT is a register to enable and disable a flash interface error interrupt (FIFERR).
When on-chip ROM is disabled, the data read from FAEINT is 00h and writing is disabled.
FAEINT is initialized by a reset.

DFLWPEIE Bit (Data Flash Programming/Erasure Protection Violation Interrupt Enable)

This bit is used to enable or disable FIFERR interrupt requests when a data flash programming/erasure protection violation occurs and the DFLWPE bit in FASTAT is set to 1.

DFLRPEIE Bit (Data Flash Read Protection Violation Interrupt Enable)

This bit is used to enable or disable FIFERR interrupt requests when a data flash read protection violation occurs and the DFLRPE bit in FASTAT is set to 1.

DFLAEIE Bit (Data Flash Read Protection Violation Interrupt Enable)

This bit is used to enable or disable FIFERR interrupt requests when a data flash access violation occurs and the DFLAE bit in FASTAT is set to 1.

CMDLKIE Bit (FCU Command Lock Interrupt Enable)

This bit is used to enable or disable FIFERR interrupt requests when a FCU command-locked state occurs and the CMDLK bit in FASTAT is set to 1.

32.2.4 Data Flash Read Enable Register 0 (DFLRE0)

Address: 007F C440h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	KEY[7:0]								DBRE07	DBRE06	DBRE05	DBRE04	DBRE03	DBRE02	DBRE01	DBRE00
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	DBRE00	DB00 Block Read Enable	0: Read disabled 1: Read enabled	R/W
b1	DBRE01	DB01 Block Read Enable		R/W
b2	DBRE02	DB02 Block Read Enable		R/W
b3	DBRE03	DB03 Block Read Enable		R/W
b4	DBRE04*1	DB04 Block Read Enable		R/W
b5	DBRE05*1	DB05 Block Read Enable		R/W
b6	DBRE06*1	DB06 Block Read Enable		R/W
b7	DBRE07*1	DB07 Block Read Enable		R/W
b15 to b8	KEY[7:0]	Key Code	Enable or disable rewriting of the DBREi bit (i = 07 to 00).	R/(W)*2

Note 1. Bits 7 to 4 are reserved in R5F562T7xxxx or R5F562T6xxxx. These bits are always read as 0. The write value should always be 0.
Note 2. Write data is not retained.

DFLRE0 is a register to enable or disable the DB00 to DB07 blocks of the data area (see Figure 32.3) to be read.
Only specific values written to the upper byte in word access are valid. Data written to the upper byte is not retained.
When on-chip ROM is disabled, the data read from DFLRE0 is 0000h and writing is disabled.
DFLRE0 is initialized by a reset.

DBREi Bit (DBi Block Read Enable) (i = 07 to 00)

This bit is used to enable or disable the DB00 to DB07 blocks of the data area to be read.
The DBREi bit is used to control reading of the DBi blocks.
Writing to the DBREi is enabled only in word access when the KEY[7:0] bits are 2Dh.

KEY[7:0] Bits (Key Code)

These bits are used to enable or disable rewriting of the DBREi bit.
Data written to the KEY[7:0] bits is not retained.

32.2.5 Data Flash Read Enable Register 1 (DFLRE1)

Address: 007F C442h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	KEY[7:0]								DBRE15	DBRE14	DBRE13	DBRE12	DBRE11	DBRE10	DBRE09	DBRE08
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	DBRE08*1	DB8 Block Read Enable	0: Read disabled 1: Read enabled	R/W
b1	DBRE09*1	DB9 Block Read Enable		R/W
b2	DBRE10*1	DB10 Block Read Enable		R/W
b3	DBRE11*1	DB11 Block Read Enable		R/W
b4	DBRE12*1	DB12 Block Read Enable		R/W
b5	DBRE13*1	DB13 Block Read Enable		R/W
b6	DBRE14*1	DB14 Block Read Enable		R/W
b7	DBRE15*1	DB15 Block Read Enable		R/W
b15 to b8	KEY[7:0]	Key Code	Enable or disable rewriting of the DBREi bit (i = 15 to 8).	R/(W) *2

Note 1. Bits 7 to 0 are reserved in R5F562T7xxxx or R5F562T6xxxx. These bits are always read as 0. The write value should always be 0.
Note 2. Write data is not retained.

DFLRE1 is a register to enable or disable the DB15 to DB08 blocks of the data area (see Figure 32.3) to be read.
Only specific values written to the upper byte in word access are valid. Data written to the upper byte is not retained.
When on-chip ROM is disabled, the data read from DFLRE1 is 0000h and writing is disabled.
DFLRE1 is initialized by a reset.

DBREi Bit (DBi Block Read Enable) (i = 15 to 08)

This bit is used to enable or disable the DB15 to DB08 blocks of the data area to be read.
The DBREi bit is used to control reading of the DBi blocks.
Writing to the DBREi is enabled only in word access when the KEY[7:0] bits are D2h.

KEY[7:0] Bits (Key Code)

These bits are used to enable or disable rewriting of the DBREi bit.
Data written to the KEY[7:0] bits is not retained.

32.2.6 Data Flash Programming/Erasure Enable Register 0 (DFLWE0)

Address: 007F C450h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	KEY[7:0]								DBWE07	DBWE06	DBWE05	DBWE04	DBWE03	DBWE02	DBWE01	DBWE00
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	DBWE00	DB00 Block Programming/Erasure Enable	0: Programming/erasure disabled 1: Programming/erasure enabled	R/W
b1	DBWE01	DB01 Block Programming/Erasure Enable		R/W
b2	DBWE02	DB02 Block Programming/Erasure Enable		R/W
b3	DBWE03	DB03 Block Programming/Erasure Enable		R/W
b4	DBWE04*1	DB04 Block Programming/Erasure Enable		R/W
b5	DBWE05*1	DB05 Block Programming/Erasure Enable		R/W
b6	DBWE06*1	DB06 Block Programming/Erasure Enable		R/W
b7	DBWE07*1	DB07 Block Programming/Erasure Enable		R/W
b15 to b8	KEY[7:0]	Key Code	Enable or disable rewriting of the DBWEi bit (i = 07 to 00).	R/(W)*2

Note 1. Bits 7 to 4 are reserved in R5F562T7xxxx or R5F562T6xxxx. These bits are always read as 0. The write value should always be 0.
Note 2. Write data is not retained.

DFLWE0 is a register to enable or disable the DB00 to DB07 blocks of the data area (see Figure 32.3) to be programmed or erased.
Only specific values written to the upper byte in word access are valid. Data written to the upper byte is not retained.
When on-chip ROM is disabled, the data read from DFLWE0 is 0000h and writing is disabled.
DFLWE0 is initialized by a reset.

DBWEi Bit (DBi Block Programming/Erasure Enable) (i = 07 to 00)

This bit is used to enable or disable the DB07 to DB00 blocks of the data area to be programmed or erased.
The DBWEi bit is used to control programming/erasure of the DBi blocks.
Programming of the DBWEi bit is enabled only in word access when the KEY[7:0] bits are 1Eh.

KEY[7:0] Bits (Key Code)

These bits are used to enable or disable rewriting of the DBWEi bit.
Data written to the KEY[7:0] bits is not retained.

32.2.7 Data Flash Programming/Erasure Enable Register 1 (DFLWE1)

Address: 007F C452h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	KEY[7:0]								DBWE15	DBWE14	DBWE13	DBWE12	DBWE11	DBWE10	DBWE09	DBWE08
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	DBWE08*1	DB08 Block Programming/Erasure Enable	0: Programming/erasure disabled 1: Programming/erasure enabled	R/W
b1	DBWE09*1	DB09 Block Programming/Erasure Enable		R/W
b2	DBWE10*1	DB10 Block Programming/Erasure Enable		R/W
b3	DBWE11*1	DB11 Block Programming/Erasure Enable		R/W
b4	DBWE12*1	DB12 Block Programming/Erasure Enable		R/W
b5	DBWE13*1	DB13 Block Programming/Erasure Enable		R/W
b6	DBWE14*1	DB14 Block Programming/Erasure Enable		R/W
b7	DBWE15*1	DB15 Block Programming/Erasure Enable		R/W
b15 to b8	KEY[7:0]	Key Code	Enable or disable rewriting of the DBWEi bit (i = 15 to 8).	R/(W) *2

Note 1. Bits 7 to 0 are reserved in R5F562T7xxxx or R5F562T6xxxx. These bits are always read as 0. The write value should always be 0.
Note 2. Write data is not retained.

DFLWE1 is a register to enable or disable the DB15 to DB08 blocks of the data area (see Figure 32.3) to be programmed or erased.
Only specific values written to the upper byte in word access are valid. Data written to the upper byte is not retained.
When on-chip ROM is disabled, the data read from DFLWE1 is 0000h and writing is disabled.
DFLWE1 is initialized by a reset.

DBWEi Bit (DBi Block Programming/Erasure Enable) (i = 15 to 08)

This bit is used to enable or disable the DB15 to DB08 blocks of the data area to be programmed or erased.
The DBWEi bit is used to control programming/erasure of the DBi blocks.
Programming of the DBWEi bit is enabled only in word access when the KEY[7:0] bits are E1h.

KEY[7:0] Bits (Key Code)

These bits are used to enable or disable rewriting of the DBWEi bit.
Data written to the KEY[7:0] bits is not retained.

32.2.8 Flash P/E Mode Entry Register (FENTRYR)

Address: 007F FFB2h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	FEKEY[7:0]								FENTRYD	—	—	—	—	—	—	FENTRY0
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	FENTRY0	ROM P/E Mode Entry 0	See section 31, ROM (Flash Memory for Code Storage).	R/W
b6 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7	FENTRYD	Data Flash P/E Mode Entry	0: Data flash is in read mode 1: Data flash is in P/E mode	R/W
b15 to b8	FEKEY[7:0]	Key Code	Enable or disable rewriting of the FENTRYD and FENTRY0 bits.	R/(W)*1

Note 1. Write data is not retained.

FENTRYR is a register to place the ROM/data flash in P/E mode.
To place ROM/data flash in P/E mode and accept commands from the FCU, either the FENTRYD or FENTRY0 bit must be set to 1. If more than one bit is set to 1, the ILGLERR bit is set in FSTATR0 and the FCU enters the command-locked state.
Only specific values written to the upper byte in word access are valid. Any other writing causes the register to be initialized. Data written to the upper byte is not retained.
When on-chip ROM is disabled, the data read from FENTRYR is 0000h and writing is disabled.
FENTRYR is initialized by a reset, or when the FRESET bit in FRESETR is set to 1.
For FSTATR0, see section 31.2.5, Flash Status Register 0 (FSTATR0).
For FRESETR, see section 31.2.10, Flash Reset Register (FRESETR).

FENTRYD Bit (Data Flash P/E Mode Entry)

The FENTRYD bit is used to place the data flash in P/E mode.
[Writing-enable conditions (when all of the following conditions are met)]

- On-chip ROM is enabled.
- The FRDY bit in FSTATR0 is set to 1
- AAh is written to the FEKEY[7:0] bits in word access.

[Setting condition]

- When the writing-enable conditions are met, FENTRYR is set to 0000h, and 1 is written to the FENTRYD bit

[Clearing conditions]

- Data is written in byte access.
- Data is written in word access when the FEKEY[7:0] bits are other than AAh.
- When the writing-enable conditions are met, 0 is written to the FENTRYD bit.
- When the writing-enable conditions are met and FENTRYR is other than 0000h, data is written to FENTRYR.

FEKEY[7:0] Bits (Key Code)

These bits enable or disable rewriting of the FENTRYD and FENTRY0 bits.
Data written to the FEKEY[7:0] bits is not retained.

32.2.9 Data Flash Blank Check Control Register (DFLBCCNT)

Address: 007F FFCAh

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	BCADR[7:0]								—	—	BCSIZE
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	BCSIZE	Blank Check Size Setting	0: The size of the area to be blank-checked is 8 bytes. 1: The size of the area to be blank-checked is 2 Kbytes.	R/W
b2, b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b10 to b3	BCADR[7:0]	Blank Check Address Setting	Set the address of the area to be checked	R/W
b15 to b11	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

DFLBCCNT is a register for specifying the address and size of the area to be checked by a blank check command.
When on-chip ROM is disabled, the data read from DFLBCCNT is 0000h and writing is disabled.
DFLBCCNT is initialized by a reset, or when the FRESET bit in FRESETR is set to 1.
For FRESETR, see section 31.2.10, Flash Reset Register (FRESETR).

BCSIZE Bit (Blank Check Size Setting)

The BCSIZE bit is used to set the size of the area to be checked by a blank check command.

BCADR[7:0] Bits (Blank Check Address Setting)

When the size of the area to be checked by a blank check command is 8 bytes (the BCSIZE bit is set to 0), this bit is used to set the address of the area to be checked.
When the BCSIZE bit is set to 0, the setting of DFLBCCNT (the setting of the BCADR[7:0] bits shifted three bits in the MSB direction) added with the erased block start address specified when issuing a blank check command is the start address of the area to be checked.

32.2.10 Data Flash Blank Check Status Register (DFLBCSTAT)

Address: 007F FFCEh

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	BCST
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	BCST	Blank Check Status	0: The area to be blank-checked is erased (blank) 1: 0 or 1 is written in the area to be blank-checked	R
b15 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

DFLBCSTAT is a register which stores the results of a blank check command.
When on-chip ROM is disabled, the data read from DFLBCSTAT is 0000h and writing is disabled.
DFLBCSTAT is initialized by a reset, or when the FRESET bit in FRESETR is set to 1.
For FRESETR, see section 31.2.10, Flash Reset Register (FRESETR).

BCST Bit (Blank Check Status)

This bit is used to indicate the results of blank checking.

32.3 Configuration of Memory Area for the Data Flash Memory

The data flash memory of products in the RX62T Group is configured as an 8-Kbyte data area. The address range occupied by this area is shown in Figure 32.2.
Note that for the data area, the address range for reading is the same as the address range for programming and erasure.

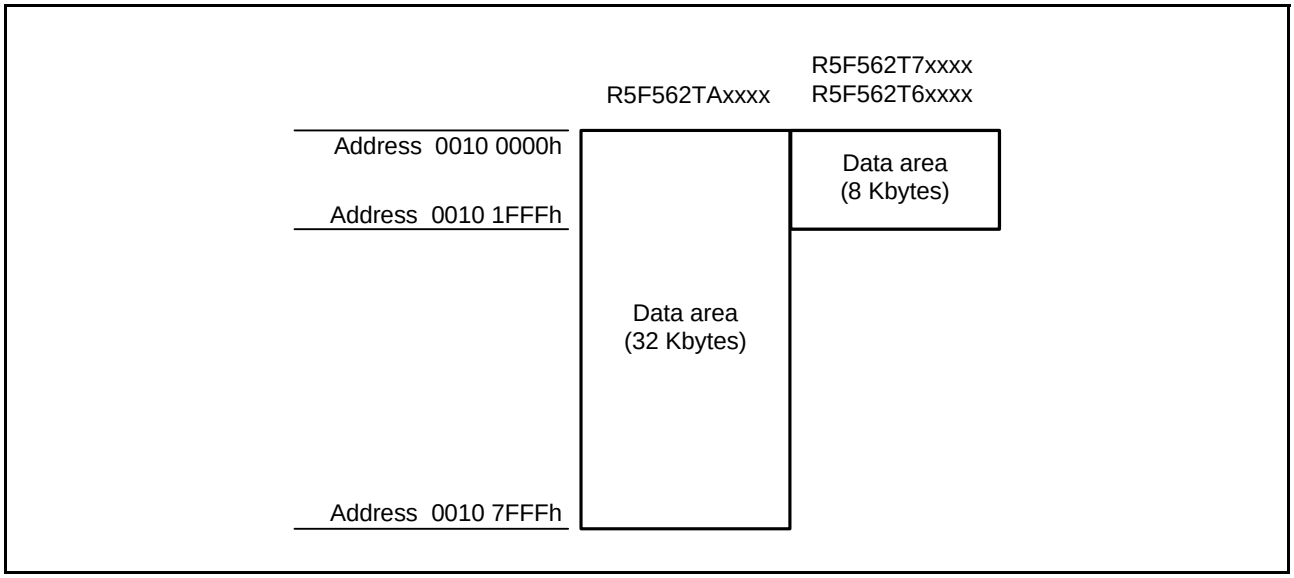


Figure 32.2 Configuration of the Data Area

32.4 Block Configuration

Figure 32.3 shows how the erasure blocks of the data area are configured. The data area is divided into four 2-Kbyte blocks, and erasure proceeds in these block units. Programming proceeds in 8- or 128-byte units. For programming in 8-byte units, each unit starts at an address where the value of the three lower-order bits is 0. For programming in 128-byte units, each unit starts at an address where the value of the lower-order bits is 00h or 80h.

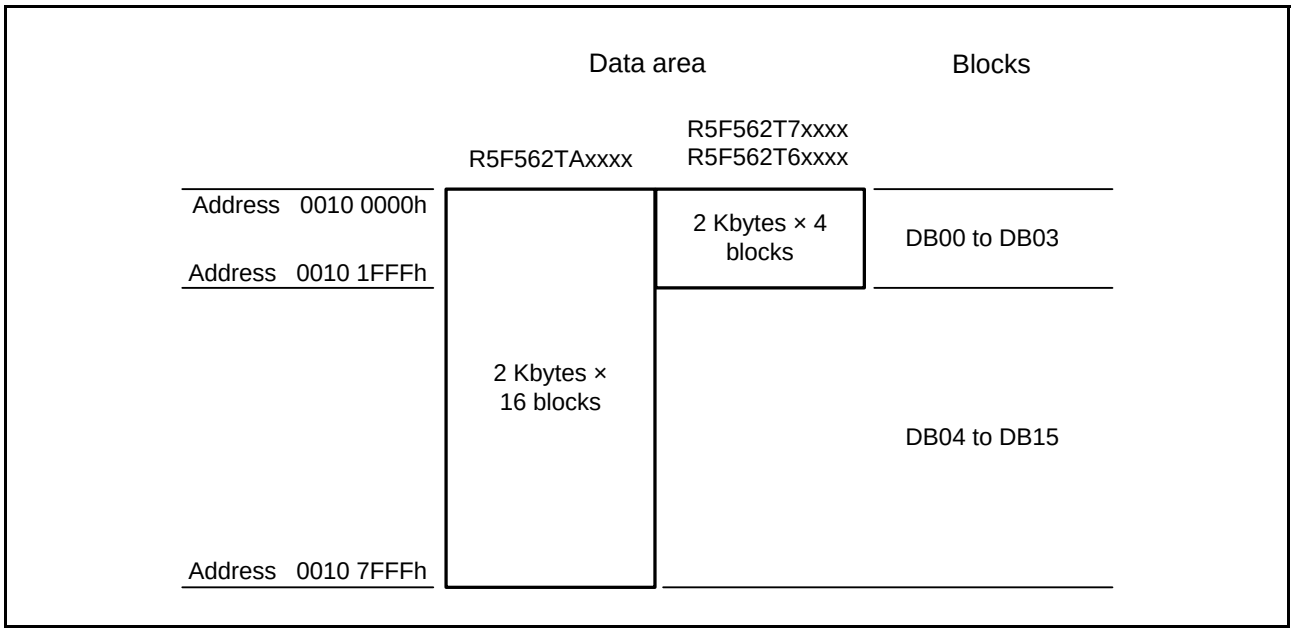


Figure 32.3 Division of the Data Area into Blocks

32.5 Operating Modes Associated with the Data Flash

For the transitions between operating modes, see section 31.5, Operating Modes Associated with the ROM.
Reading, programming, and erasing of the data flash memory in an on-board device can proceed if the device is in boot mode or single-chip mode (with on-chip ROM enabled).
The differences between modes are indicated in Table 32.4.

Table 32.4 Differences between Modes

Item	Boot Mode	Single-Chip Mode (with On-chip ROM Enabled)
Environment for programming and erasure	On-board programming	On-board programming
Programmable and erasable area	Data area	Data area
Division into erasure blocks	Possible*1	Possible
Target area for booting after a reset	Area containing the embedded program*2	User area

Note 1. All flash memory areas may be erased at the time of booting up. Specified blocks can subsequently be erased. For details, refer to section 31.9.2, ID Code Protection in Boot Mode.
Note 2. Not available to users.

- In boot mode, a host is able to program or read out the data area via an SCI.
- In boot mode, on-chip RAM is employed for the embedded program for use in boot mode. For this reason, preserving the contents of on-chip RAM is not possible in this case.

32.6 Programming and Erasing the Data Flash Memory

The data flash memory is programmed and erased by issuing commands to a dedicated sequencer (FCU) for programming and erasure. The FCU has five modes. For programming and erasure, the mode is changed and then commands for programming and erasure are issued.
The mode transitions required to program or erase the data flash and the system of commands are described below. The descriptions apply in common to boot mode and single-chip mode (with on-chip ROM enabled).

32.6.1 FCU Modes

The FCU has five modes or sets of modes. Transitions between modes are caused by writing to the FENTRYR register or issuing FCU commands. Figure 32.4 is a diagram of the FCU mode transitions.

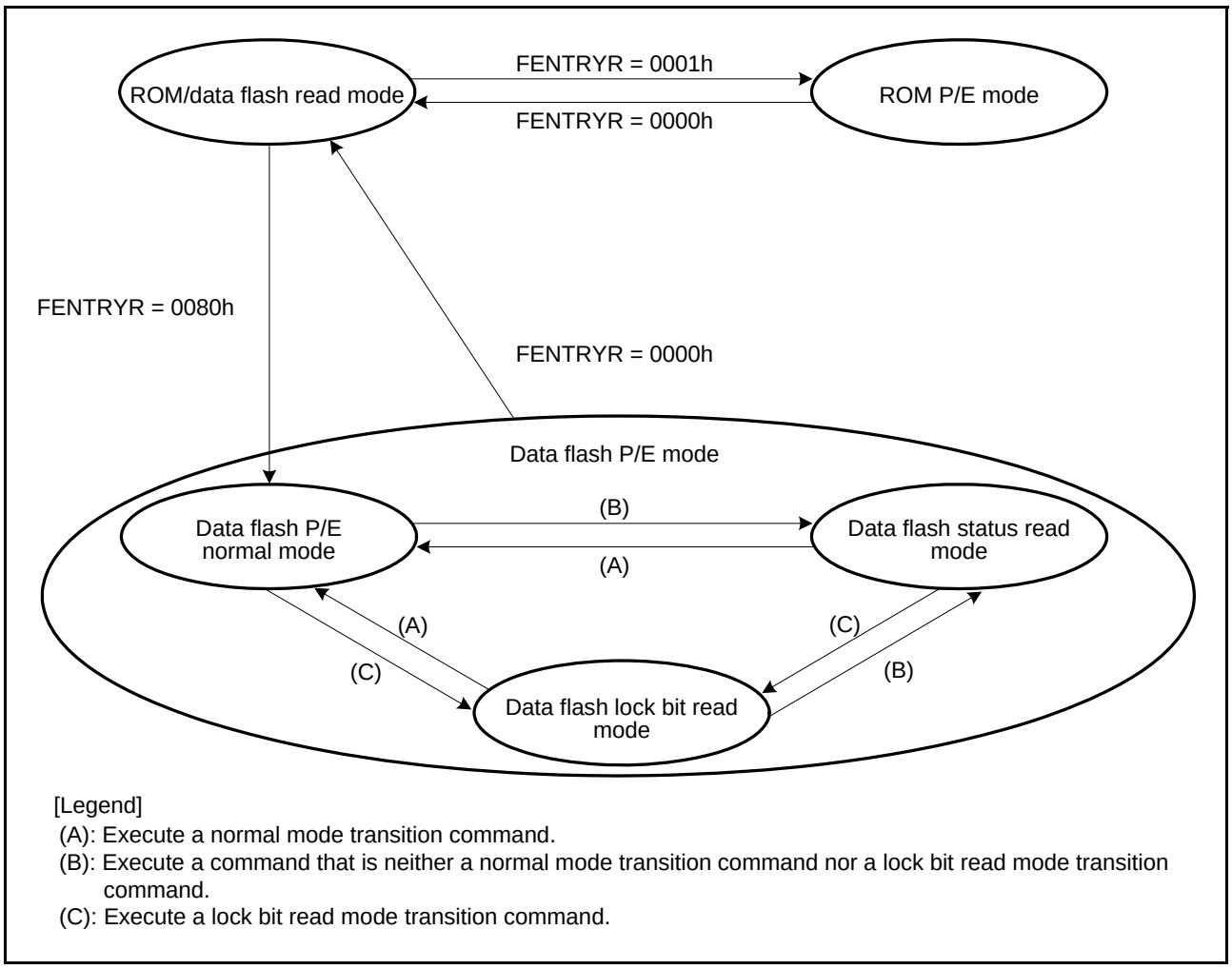


Figure 32.4 Mode Transitions of the FCU (Associated with the Data Flash)

32.6.1.1 ROM P/E Modes

The ROM P/E modes are for programming and erasure of the ROM.
For details on the ROM P/E modes, see section 31.6.1.2, ROM P/E Modes.

32.6.1.2 ROM/Data Flash Read Mode

This mode is for reading the ROM or data flash memory. The FCU does not accept commands.
The FCU enters this mode when both the FENTRYD bit and FENTRY0 bit in FENTRYR are set to 0.

32.6.1.3 Data Flash P/E Modes

These modes are for programming and erasure of the data flash memory. Reading out the data flash is not possible.
Data flash P/E normal mode, data flash status read mode, and data flash lock-bit read mode are the three data flash P/E modes.

(1) Data Flash P/E Normal Mode

The transition to data flash P/E normal mode is the first transition in the process of programming or erasing the data flash. The FCU enters this mode when the FENTRYD bit in FENTRYR is set to 1 and the FENTRY0 bit in FENTRYR is set to 0 in ROM/data flash read mode, or when the normal mode transition command is received in data flash P/E modes. Table 32.7 lists the acceptable commands in this mode.
Read access to an address within the data flash area causes a data-flash-access violation, and the FCU enters the command-locked state. High-speed reading of the ROM is possible.

(2) Data Flash Status Read Mode

The data flash status read mode is for reading information on the state of the data flash.
The FCU enters this mode when a command other than the normal mode transition and lock bit read mode transition command is received in data flash P/E modes. Data flash status read mode encompasses the states where the FRDY bit in FSTATR0 is 0 and the command-locked state after an error has occurred. Table 32.7 lists the acceptable commands in this mode.
Read access to an address within the data flash area will actually read out the value of the FSTATR0 register. High-speed reading of the ROM is possible.

(3) Data Flash Lock-Bit Read Mode

The data flash lock-bit read mode is for reading the values of the lock bits of the data flash. However, this is not possible because the data flash does not have lock bits.
The FCU enters this mode when a lock-bit read mode transition command is received in data flash P/E modes. Table 32.7 lists the acceptable commands in this mode.
Since the data flash does not have lock bits, data read out in read access to addresses within the data flash area are undefined. However, the access does not lead to a data-flash-access violation. High-speed reading of the ROM is possible.

32.6.2 FCU Commands

FCU commands consist of commands for mode transitions of the FCU and of commands for programming and erasure. Table 32.5 lists the FCU commands for use with the data flash.

Table 32.5 FCU Commands for Use with Data Flash Memory

Command	Description
P/E Normal mode transition	Changes the mode to normal mode (see section 32.6.3, Connections between FCU Modes and Commands)
Status read mode transition	Changes the mode to status read mode (seesection 32.6.3, Connections between FCU Modes and Commands)
Lock bit read mode transition (lock bit read 1)	Changes the mode to lock bit read mode (see section 32.6.3, Connections between FCU Modes and Commands)
Peripheral clock notification	Sets the frequency of the peripheral clock
Programming	Data flash programming (in 8-byte or 128-byte units)
Block erasure	Data flash erasure (in block units, with the lock bit being erased simultaneously)
P/E suspension	Suspends programming/erasure
P/E resumption	Resumes programming/erasure
Status register clearing	Clears the ILGLERR, ERSERR and PRGERR bits in FSTATR0 and releases the FCU from the command-locked state
Lock bit read 2/blank checking	Checks whether the specified block of data flash memory has been erased (is blank)

Commands other than the blank-checking command are also for use with the ROM.
The blank-checking command for the data flash memory is also used as the lock bit read 2 command for the ROM. That is, when the same command is issued for the ROM, a lock bit of the ROM is read out.
Commands for the FCU are issued by write access to addresses within the data flash area.
Table 32.6 shows the formats of the programming commands and the blank checking command. For the formats of FCU commands other than programming and blank checking commands, see section 31.6.2, FCU Commands in section 31, ROM (Flash Memory for Code Storage)).
Write access as listed in Table 32.6 and in accord with certain conditions causes the FCU to execute processing for the corresponding command. For details on the conditions for acceptance of the individual FCU commands, see section 32.6.3, Connections between FCU Modes and Commands. For how to use the FCU commands, see section 32.6.4, FCU Command Usage.

Table 32.6 FCU Command Formats

Command	Number of bus cycles	First Cycle		Second Cycle		Third Cycle		4th to (N+2)th Cycles		(N+3)th Cycles	
		Address	Data	Address	Data	Address	Data	Address	Data	Address	Data
Programming (8-byte programming; n = 4)	7	EA	E8h	EA	04h	WA	WDn	EA	WDn	EA	D0h
Programming (128-byte programming; n = 64)	67	EA	E8h	EA	40h	WA	WDn	EA	WDn	EA	D0h
Blank checking	2	EA	71h	BA	D0h	—	—	—	—	—	—

Address column EA: Address within the data flash area. Any address in the range from 0010 0000h to 0010 1FFFh.
WA: Start address in 8-byte or 128-byte.
BA: Address in an erasure block of the data flash. Any address within the target erasure block.
Data columns WDn: nth word of data for programming (n = 1 to N)

32.6.3 Connections between FCU Modes and Commands

The sets of FCU commands that can be accepted in each of the FCU modes are fixed. Furthermore, which commands are acceptable in a given FCU mode varies according to the state of the FCU.
Issuing of an FCU command must follow checking of the FCU's state after transitions of the FCU mode.
Commands that are acceptable in the various FCU modes and states are listed in Table 32.7. Issuing a command that is not currently acceptable leads to the FCU being placed in the command-locked state (see section 32.7.2, Error Protection).
Issuing of an FCU command must follow checking of the values of the FRDY, ILGLERR, ERSERR, and PRGERR bits in FSTATR0 and of the FCUERR bit in FSTATR1 after transitions of the FCU mode. Furthermore, the CMDLK bit in FASTAT can be checked to see if an error has occurred. The value of the CMDLK bit in FASTAT is the logical OR of the ILGLERR, ERSERR, and PRGERR bits in FSTATR0 and the FCUERR bit in FSTATR1.

Table 32.7 Acceptable Commands and the State and Mode (Data Flash P/E Mode) of the FCU

Command	P/E Normal Mode			Status read mode							Lock-bit read mode		
	Programming suspended	Erasure suspended	Other state	Programming or erasure	Processing to suspend programming or erasure	Blank checking	Programming suspended	Erasure suspended	Command-locked state	Other state	Programming suspended	Erasure suspended	Other state
FSTATR0.FRDY bit	1	1	1	0	0	0	1	1	0/1	1	1	1	1
FSTATR0.SUSRDY bit	0	0	0	1	0	0	0	0	0	0	0	0	0
FSTATR0.ERSSPD bit	0	1	0	0	0/1	0	0	1	0	0	0	1	0
FSTATR0.PRGSPD bit	1	0	0	0	0/1	0	1	0	0	0	1	0	0
FASTAT.CMDLK bit	0	0	0	0	0	0	0	0	1	0	0	0	0
P/E Normal mode transition	A	A	A	X	X	X	A	A	X	A	A	A	A
Status read transition	A	A	A	X	X	X	A	A	X	A	A	A	A
Lock-bit read transition (lock bit read 1)	A	A	A	X	X	X	A	A	X	A	A	A	A
Peripheral clock setting	X	X	A	X	X	X	X	X	X	A	X	X	A
Programming	X	*	A	X	X	X	X	*	X	A	X	*	A
Block erasure	X	X	A	X	X	X	X	X	X	A	X	X	A
P/E suspension	X	X	X	A	X	X	X	X	X	X	X	X	X
P/E resumption	A	A	X	X	X	X	A	A	X	X	A	A	X
Status register clearing	A	A	A	X	X	X	A	A	A	A	A	A	A
Blank checking	A	A	A	X	X	X	A	A	X	A	A	A	A

A: Acceptable
*: Only programming is acceptable for blocks other than the block where erasure was suspended
X: Not acceptable

32.6.4 FCU Command Usage

This section shows how to program and erase the data flash memory by using programming and block erasure commands, respectively, and how to check the state of erasure of the data flash by using the blank check command. For the method for transferring the firmware to the FCU RAM and the ways to use other FCU commands, see section 31.6.4, FCU Command Usage in section 31, ROM (Flash Memory for Code Storage).

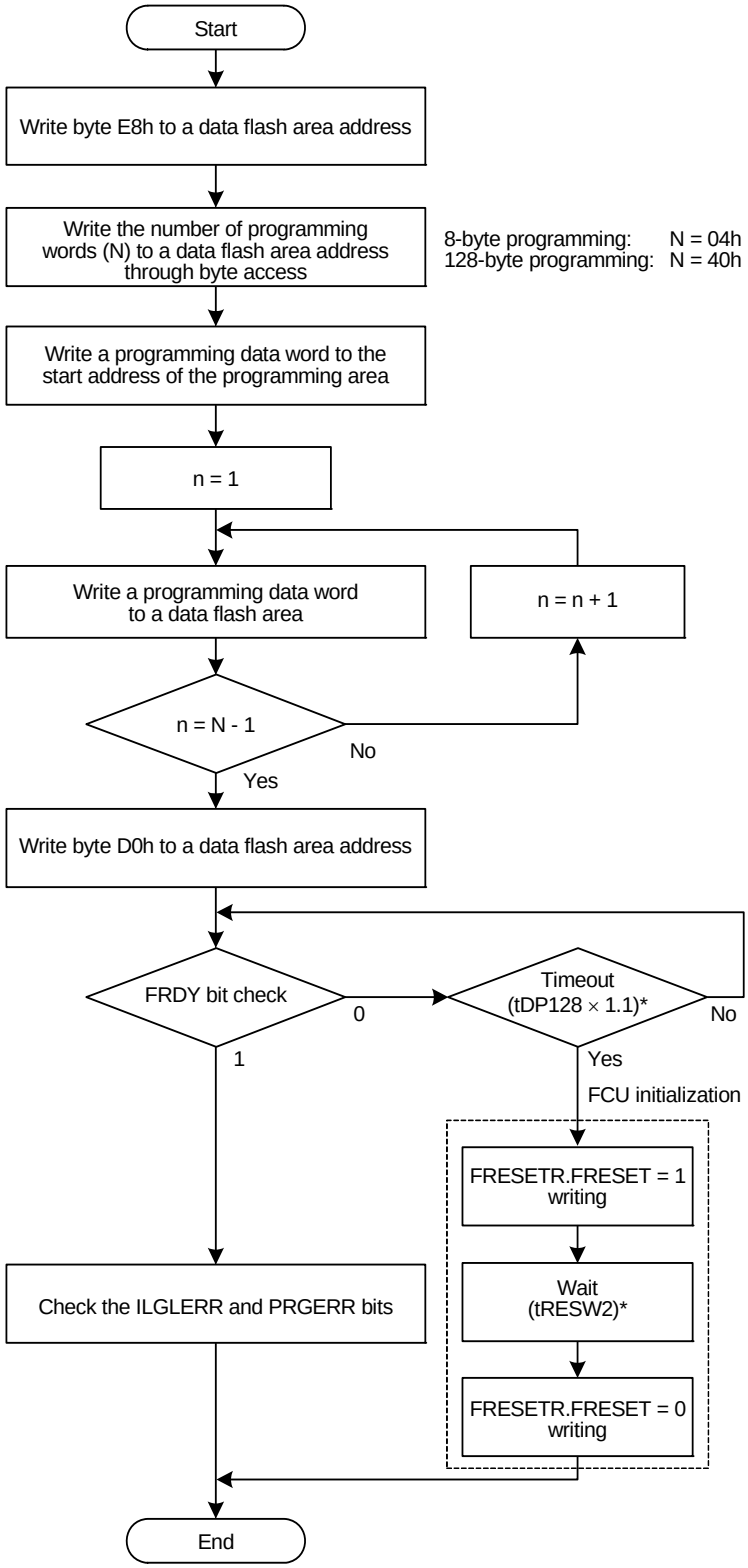
(1) Using the Peripheral Clock Notification Command

This command handles notification of the frequency of the peripheral clock. For details, see section 31.6.4, FCU Command Usage in section 31, ROM (Flash Memory for Code Storage). Set the FENTRYD bit in FENTRYR to 1 and make settings to indicate an address within the data flash area.

(2) Programming

To program the data flash, use one of the programming commands.
Use byte access to write E8h to an address within the data flash area in the first cycle of the programming command, and the number of words (N)*1 to be programmed in the second cycle. Access the peripheral bus in words from the third cycle to cycle N + 2 of the command. In the third cycle, write the first word of data for programming to the address where the target area for programming starts. This address must be on an 8-byte boundary for 8-byte programming or on a 128-byte boundary address for 128-byte programming. After writing words to addresses in the data flash area N times, write byte D0h to an address within the data flash area in cycle N + 3; the FCU will then start actual programming of the data flash. Read the FRDY bit in FSTATR0 to confirm the completion of data flash programming.
If the area accessed in the third cycle to cycle N + 2 includes addresses that do not require programming, write FFFFh as the programming data for those addresses. To ignore the programming and erasure protection provided by the DFLWEk (k = 0, 1) setting, set the program/erase enable bit for the target block to 1 before programming starts.
Figure 32.5 shows the procedure for data flash programming.

Note 1. N = 04h for 8-byte programming or N = 40h for 128-byte programming.



Note: * tDP128: Time required for programming 128-byte data (see section 33, Electrical Characteristics)
tRESW2: Reset pulse width during programming/erasure (see section 33, Electrical Characteristics)

Figure 32.5 Procedure for Data Flash Programming

(3) Erasure

To erase the data flash, use the block erasure command. The data flash is erased in the same way as the ROM (see section 31, ROM (Flash Memory for Code Storage)).
Note that the data flash has a programming and erasure protection function that is controlled by DFLWEk (k = 0, 1). Erasure can only be performed with protection provided by the DFLWEk (k = 0, 1) setting disabled, so set the programming/erasure enable bit for the target erasure block to 1 before issuing the erasure command.

(4) Blank Checking

Since using the CPU to read erased areas of the data flash produces undefined values, the blank checking command should be used to check whether the data flash has actually been erased. To make the blank checking command available for use, start by setting the FRDMD bit in FMODR to 1 to enable the command, and then specify the size and start address of the target area in DFLBCCNT. If the BCSIZE bit of DFLBCCNT is set to 1, checking will be performed for the entire erasure block (2 Kbytes) specified in the second cycle of the command. If the BCSIZE bit is set to 0, checking will be performed on the 8-byte range starting from the address obtained by adding the start address of the erased area as specified in the second cycle of the command and the value held by DFLBCCNT. In the first cycle of the command sequence, the value 71h is written as a byte unit to an address in the data flash. In the second cycle, when the value D0h is written to an address within the target area, the FCU starts blank checking of the data flash. Test the FRDY bit in the FSTATR0 register to check whether or not the check is complete. On completion of blank checking, check the BCST bit of DFLBCSTAT to see whether the target area has been erased or is filled with 0s and/or 1s via.
Figure 32.6 shows the procedure for blank checking of the data flash.

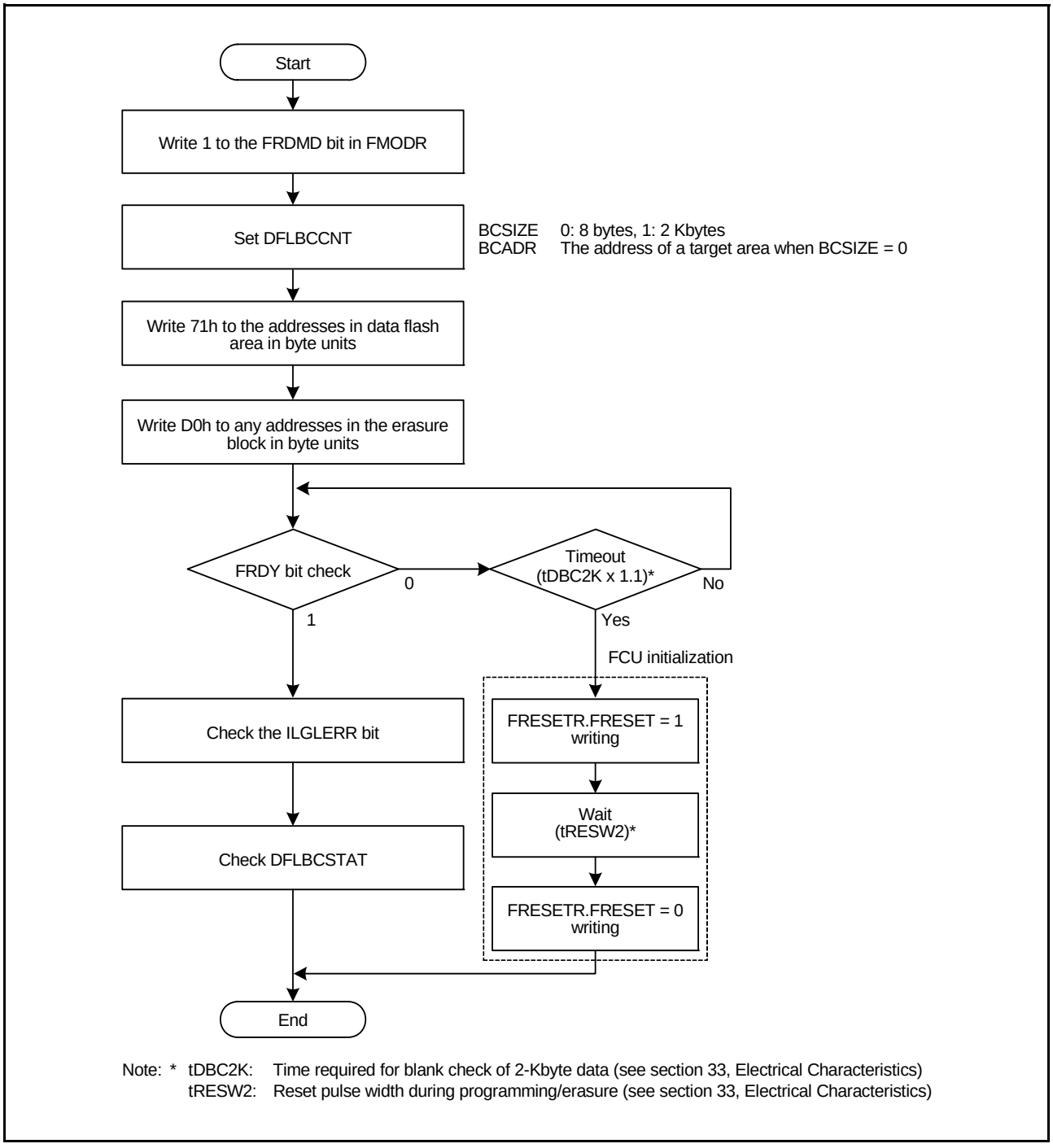


Figure 32.6 Procedure for Blank Checking of the Data Flash

32.7 Protection

There are two types of data flash programming/erasure protection: software protection and error protection.

32.7.1 Software Protection

In the software protection function, control register settings are used to disable data flash programming and erasure. If an attempt is made to issue a programming or erasure command for the data flash and the command violates current software protection, the FCU detects the error and enters the command-locked state.

(1) Protection through FWEPROR

If the FLWE[1:0] bits in FWEPROR are not set to 01b, programming cannot be performed in any mode.

(2) Protection through FENTRYR

When the FENTRYD bit in FENTRYR is 0, the ROM/data flash read mode is selected. Since the FCU does not accept commands in ROM/data flash read mode, data flash programming and erasure are disabled. If an attempt is made to issue an FCU command for the data flash in ROM/data flash read mode, the FCU detects an illegal command error and enters the command-locked state (see section 32.7.2, Error Protection).

(3) Protection through DFLWEk

When the DBWEi (i = 15 to 00) bit in DFLWEk (k = 0, 1) is 0, programming and erasure of block DBi in the data area is disabled. If an attempt is made to program or erase block DBi while the DBWEi bit is 0, the FCU detects a programming/erasure protection error and enters the command-locked state (see section 32.7.2, Error Protection).

(4) Protection through DFLREk

When the DBREi (i = 15 to 00) bit in DFLREk (k = 0, 1) is 0, reading of block DBi in the data area is disabled. If an attempt is made to read block DBi while the DBREi bit is 0, the FCU detects a read protection error and enters the command-locked state (see section 32.7.2, Error Protection).

32.7.2 Error Protection

Error protection is the detection of errors in the issuing of FCU commands and of prohibited access, and response in the form of notification of the FCU malfunction and prohibition of the reception of further commands by the FCU (the FCU enters the command-locked state). When the FCU enters the command-locked state (FASTAT.CMDLK bit is 1), one or several of the status bits (FSTATR0.ILGLERR, ERSERR, and PRGERR bits, FSTATR1.FCUERR bit, and FASTAT.DFLAE, DFLRPE, and DFLWPE bits) are set to 1 and programming and erasure of the data-flash are prohibited by placing the FCU in the command-locked state. To release the FCU from the command-locked state, a status register clearing command must be issued with FASTAT set to 10h.

While the CMDLKIE bit in FAEINT is 1, a flash interface error (FIFERR) interrupt will be generated if the FCU enters the command-locked state (the CMDLK bit in FASTAT becomes 1). While a data flash-related interrupt enable bit (DFLAEIE, DFLRPEIE, or DFLWPEIE) in FAEINT is 1, an FIFERR interrupt will also be generated if the corresponding status bit (DFLAE, DFLRPE, or DFLWPE) in FASTAT becomes 1.

Table 32.8 shows the error protection types for the data flash and the values of the status bits (the ILGLERR, ERSERR, and PRGERR bits in FSTATR0 and the DFLAE, DFLRPE, and DFLWPE bits in FASTAT) after the detection of each type of error. For the error protection types used in common by the ROM and data flash (FENTRYR setting error, most illegal command errors, erasing errors, programming errors, and FCU errors, see section 31.8.2, Error Protection in section 31, ROM (Flash Memory for Code Storage).

If the FCU enters the command-locked state due to a command other than a suspension command issued during programming or erasure processing, the FCU continues programming or erasing the data flash. In this state, the P/E suspension command cannot suspend programming or erasure. If a command is issued in the command-locked state, the ILGLERR bit becomes 1.

Table 32.8 Error Protection Types (for Data Flash Only)

Error	Description	ILGLERR	ERSERR	PRGERR	DFLAE	DFLRPE	DFLWPE	CMDLK
Illegal command error	The value specified in the second cycle of a programming command was neither 04h nor 40h.	1	0	0	0	0	0	1
	A lock bit programming command was issued for an area in the data flash while the FENTRYD bit of FENTRYR register was set to 1.	1	0	0	0	0	0	1
Data flash access error	A read access command was issued for the data flash area while FENTRYD = 1 in FENTRYR in data flash P/E normal mode.	1	0	0	1	0	0	1
	A write access command was issued for the data flash area while FENTRYD = 0.	1	0	0	1	0	0	1
	An access command was issued for the data flash area while the FENTRY0 bit in FENTRYR was 1.	1	0	0	1	0	0	1
Data flash read protect error	A read access command was issued for the data flash area while it was protected against reading by the DFLREk (k = 0, 1) setting.	1	0	0	0	1	0	1
Data flash programming protect error	A program/block erase command was issued for the data flash area while it was protected against programming or erasure by the DFLWEk (k = 0, 1) setting.	1	0	0	0	0	1	1

32.8 Boot Mode

To program or erase the data area in boot mode, send control commands and programming data from the host. For the system configuration and settings in boot mode, see section 31.9, Boot Mode. This section describes only the commands dedicated for the data flash.

32.8.1 Inquiry/Selection Host Commands

Table 32.9 shows the inquiry/selection host commands dedicated to the data flash. The data area inquiry and data area information inquiry commands are used in the step of "Inquiry regarding area programming information" in the flowchart shown in Figure 31.29 (Example of Procedure to Use Inquiry/Selection Host Commands for User Area/User Boot Area) in section 31.9.5, Inquiry/Selection Host Command Wait State.

Table 32.9 Inquiry/Selection Host Commands (only for Data Flash)

Host Command Name	Function
Data area inquiry	Inquires regarding the availability of data area
Data area information inquiry	Inquires regarding the number of data areas and the start and end addresses

Each host command is described in detail below. The "command" in the description indicates a command sent from the host to the RX62T and the "response" indicates a response sent from the RX62T to the host. The "checksum" is byte-size data calculated so that the sum of all bytes to be sent by the RX62T becomes 00h.

(1) Data Area Inquiry

In response to a data area inquiry command sent from the host, the RX62T returns the information concerning the availability of data areas.

Command	2Ah			
Response	3Ah	Size	Area availability	SUM

Size (1 byte): Number of characters in the area availability field (fixed at 1)
Area availability (1 byte): Availability of data areas (fixed at 21h)
21h: Data area is available
SUM (1 byte): Checksum

(2) Data Area Information Inquiry

In response to a data area information inquiry command sent from the host, the RX62T returns the number of data area areas and their addresses.

Command	2Bh

Response			
	3Bh	Size	Area count
	Area start address		
	Area end address		
	Area start address		
	Area end address		
	:		
	Area start address		
	Area end address		
	SUM		

Size (1 byte): Total number of bytes in the area count, area start address, and area end address fields
Area count (1 byte): Number of data area areas (consecutive areas are counted as one area)
Area start address (4 bytes): Start address of a data area
Area end address (4 bytes): End address of a data area
SUM (1 byte): Checksum

The information concerning the block configuration in the data area is included in the response to the erasure block information inquiry command (see section 31.9.5, Inquiry/Selection Host Command Wait State).

32.8.2 Programming/Erasing Host Commands

Table 32.10 shows the programming/erasing host commands dedicated to the data flash. Data flash-dedicated host commands are provided only for checksum and blank check of the data flash; the programming, erasing, and reading commands are used in common for the ROM and data flash.
To program the data area, issue from the host a user area programming selection command and then a 256-byte programming command specifying a data area address as the programming address. To erase the data area, issue an erasure selection command and then a block erasure command specifying an erasure block in the data area. The information concerning the erasure block in the data area is included in the response to the erasure block information inquiry command. To read data from the data area, select the user area through a memory read command specifying a data area address as the read address.
For the user area programming selection, 256-byte programming, erasure selection, block erasure, and memory read commands, refer to section 31.9.7, Programming/Erasure Host Command Wait State. For the erasure block information inquiry command, refer to section 31.9.5, Inquiry/Selection Host Command Wait State.

Table 32.10 Programming/Erasure Host Commands (only for Data Flash)

Host Command Name	Function
Data area checksum	Performs checksum verification for the data area
Data area blank check	Checks whether the data area is blank

Each host command is described in detail below. The "command" in the description indicates a command sent from the host to the RX62T and the "response" indicates a response sent from the RX62T to the host. The "checksum" is byte-size data calculated so that the sum of all bytes to be sent by the RX62T becomes 00h.

(1) Data Area Checksum

In response to a data area checksum command sent from the host, the RX62T sums the data area data in byte units and returns the result (checksum).

Command	61h			
Response	71h	Size	Area checksum	SUM

Size (1 byte): Number of bytes in the area checksum field (fixed at 4)
Area checksum (4 bytes): Checksum of the data area data
SUM (4 bytes): Checksum (for the response data)

(2) Data Area Blank Check

In response to a data area blank check command sent from the host, the RX62T checks whether the data area is completely erased. When the data area is completely erased, the RX62T returns a response (06h). If the data area has an unerased area, the RX62T returns an error response (sends E2h and 52h in that order).

Command	62h	
Response	06h	
Error response	E2h	52h

32.9 Usage Notes

(1) Protection of Data Area Immediately after a Reset

As the initial values of DFLREk and DFLWEk (k = 0, 1) are 0000h, programming, erasure, and reading of the data area are disabled immediately after a reset. To read data from the data area, set DFLREk appropriately before accessing the data area. To program or erase the data area, set DFLWEk appropriately before issuing an FCU command for programming or erasure. If an attempt is made to read, program, or erase the data area without setting the registers, the FCU detects the error and enters the command-locked state.

(2) Other Points to Note

The other points to note are the same as for the ROM. See section 31.12, Usage Notes. However, data-flash memory also has a blank-checking facility. Accordingly, for “programming and erasure”, please read “programming, erasure, and blank checking”.

33. Electrical Characteristics

33.1 Absolute Maximum Ratings

Table 33.1 Absolute Maximum Ratings

Item	Symbol	Value	Unit
Power supply voltage	VCC PLLVCC	-0.3 to +6.5	V
Input voltage (except for ports 4 to 6)	V_{IN}	-0.3 to VCC+0.3	V
Input voltage (port 4)	V_{IN}	-0.3 to AVCC0+0.3	V
Input voltage (ports 5 and 6)	V_{IN}	-0.3 to AVCC+0.3	V
Analog power supply voltage	AVCC0, AVCC*1	-0.3 to +6.5	V
Reference power supply voltage	VREFH0*1	-0.3 to AVCC0+0.3	V
	VREF*1	-0.3 to AVCC+0.3	
Analog input voltage (port 4)	V_{AN}	-0.3 to AVCC0+0.3	V
Analog input voltage (ports 5 and 6)	V_{AN}	-0.3 to AVCC+0.3	V
Operating temperature	T_{opr}	-40 to +85	°C
Storage temperature	T_{stg}	-55 to +125	°C

Caution: Permanent damage to the LSI may result if absolute maximum ratings are exceeded.

Note 1. Do not leave the AVCC0, VREFH0, VREFL0, AVSS0, AVCC, VREF, and AVSS pins open circuit even if the A/D converter is not to be used.
- When the 12-bit converter is not in use:
  Connect the AVCC0 pin to AVCC (or VCC for a 64-pin product), the VREFH0 pin to VREF (or AVCC or VCC for an 80- or 64-pin product, respectively), and the AVSS0 and VREFL0 pins to VSS.
- When the 10-bit converter is not in use:
  Connect the AVCC pin to AVCC0, the VREF pin to VREFH0, and the AVSS pin to AVSS0.
- When neither the 10- nor the 12-bit converter is in use:
  Connect the AVCC0, VREFH0, AVCC, and VREF pins to VCC, and the AVSS0, VREFL0, and AVSS pins to VSS.

33.2 DC Characteristics

Table 33.2 DC Characteristics (1) (1 / 3)

Note: Items for which test conditions are not specifically stated in the table below have the same values under conditions 1 to 3.

Condition 1: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 3.0 to 3.6 V, VREFH0 = 3.0 V to AVCC0, VREF = 3.0 V to AVCC

Condition 2: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC

Condition 3: VCC = PLLVCC = 4.0 to 5.5 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC
Ta = -40 to +85°C. Ta is the same under conditions 1 to 3.

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Schmitt trigger input voltage	CAN input pin IRQ input pin MTU3 input pin POE3 input pin SCI input pin A/D trigger input pin NMI input pin GPT input pin LIN input pin RES#	V_{IH}	VCC×0.8	-	VCC+0.3	V	
		V_{IL}	-0.3	-	VCC×0.2		
		ΔV_T	VCC ×0.06	-	-		
	RIIC input pin (IICBus)	V_{IH}	VCC×0.7	-	VCC+0.3		
		V_{IL}	-0.3	-	VCC×0.3		
		ΔV_T	VCC ×0.05	-	-		
	Port 4*1 (also usable as an analog port)	V_{IH}	AVCC0 ×0.8	-	AVCC0 +0.3		
		V_{IL}	- 0.3	-	AVCC0 ×0.2		
		ΔV_T	AVCC0 ×0.06	-	-		
	Ports 5 and 6*1 (also usable as analog ports)	V_{IH}	AVCC ×0.8	-	AVCC +0.3		
		V_{IL}	-0.3	-	AVCC ×0.2		
		ΔV_T	AVCC ×0.06	-	-		
	Ports 1 to 3*1 Ports 7 to B*1 Ports D, E, and G*1	V_{IH}	VCC×0.8	-	VCC+0.3		
		V_{IL}	-0.3	-	VCC×0.2		
		ΔV_T	VCC ×0.06	-	-		
Input high voltage (except Schmitt trigger input pin)	MD pin, EMLE	V_{IH}	VCC×0.9	-	VCC+0.3	V	
	EXTAL RSPI input pin		VCC×0.8		VCC+0.3		
	RIIC input pin (SMBus)		2.1		VCC+0.3		Conditions 1 and 2
Input low voltage (except Schmitt trigger input pin)	MD pin, EMLE	V_{IL}	-0.3	-	VCC×0.1	V	
	EXTAL RSPI input pin		-0.3	-	VCC×0.2		
	RIIC input pin (SMBus)		-0.3	-	0.8		Conditions 1 and 2

Table 33.2 DC Characteristics (1) (2 / 3)

Note: Items for which test conditions are not specifically stated in the table below have the same values under conditions 1 to 3.

Condition 1: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 3.0 to 3.6 V, VREFH0 = 3.0 V to AVCC0, VREF = 3.0 V to AVCC

Condition 2: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC

Condition 3: VCC = PLLVCC = 4.0 to 5.5 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC
Ta = -40 to +85°C. Ta is the same under conditions 1 to 3.

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Output high voltage	All output pins (except for P71 to P76 and P90 to P95)	V_{OH}	VCC-0.5	-	-	V	I_{OH} = -1 mA
	P71 to P76		VCC-0.5	-	-		I_{OH} = -1mA 64-pin LQFP Condition 3
			VCC-1.0	-	-		I_{OH} = -5mA 64-pin LQFP Other than condition 3
	P90 to P95		VCC-0.5	-	-		I_{OH} = -1mA 80-pin LQFP or 64-pin LQFP
			VCC-1.0	-	-		I_{OH} = -5 mA 112-pin LQFP or 100-pin LQFP
Output low voltage	All output pins (except for P71 to P76, P90 to P95, and RIIC)	V_{OL}	-	-	0.5	V	I_{OL} = 1.0 mA
	P71 to P76		-	-	0.5		I_{OL} = 1.0 mA 64-pin LQFP Other than condition 3
			-	-	1.1		I_{OL} = 15 mA Conditions 1 and 2
			-	-	1.4		I_{OL} = 15 mA Other than 64-pin LQFP Condition 3
	P90 to P95		-	-	0.5		I_{OL} = 1.0 mA 80-pin LQFP or 64-pin LQFP
			-	-	1.1		I_{OL} = 15 mA 112-pin LQFP or 100-pin LQFP Conditions 1 and 2
			-	-	1.4		I_{OL} = 1 mA 112-pin LQFP or 100-pin LQFP Condition 3
	RIIC pin		-	-	0.4		I_{OL} = 3 mA
			-	-	0.6		I_{OL} = 6 mA
Input leakage current	RES#, MD pin, EMLE	$\lvert I_{in} \rvert$	-	-	1.0	µA	V_{in} = 0 V, V_{in} = VCC
Three-state leakage current (off state)	Ports 1 to A, PB0, PB3 to PB7, D, E, G	$\lvert I_{TSI} \rvert$	-	-	1.0	µA	V_{in} = 0 V, V_{in} = VCC
	Ports PB1 and PB2		-	-	5.0		

Table 33.2 DC Characteristics (1) (3 / 3)

Note: Items for which test conditions are not specifically stated in the table below have the same values under conditions 1 to 3.

Condition 1: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 3.0 to 3.6 V, VREFH0 = 3.0 V to AVCC0, VREF = 3.0 V to AVCC

Condition 2: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC

Condition 3: VCC = PLLVCC = 4.0 to 5.5 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC
Ta = -40 to +85°C. Ta is the same under conditions 1 to 3.

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Input capacitance	All input pins (except for ports PB1 and PB2)	C_{in}	-	-	15	pF	V_{in} = 0 V, f = 1 MHz, T_a = 25°C
	Ports PB1 and PB2		-	-	30		

Note 1. This includes the multiplexed input pins, except in cases where port pins PB1 and PB2 are used as RIIC input pins or port pins P22 to P24, P30, PA3 to PA5, PB0, PD0 to PD2, or PD6 are used as RSPI input pins.

Table 33.3 DC Characteristics (2)

Note: Items for which test conditions are not specifically stated in the table below have the same values under conditions 1 to 3.

Condition 1: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 3.0 to 3.6 V, VREFH0 = 3.0 V to AVCC0, VREF = 3.0 V to AVCC

Condition 2: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC

Condition 3: VCC = PLLVCC = 4.0 to 5.5 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC
Ta = -40 to +85°C. Ta is the same under conditions 1 to 3.

Item			Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Supply current*1	In operation	Max.*2	I_{CC}*3	-	-	70	mA	ICLK = 100 MHz PCLK = 50 MHz
		Normal*4		-	35	-		
		Increased by BGO operation*5		-	15	-		
	Sleep				22	60		
	All-module-clock-stop mode*6				14	28		
	Standby mode	Software standby mode		-	0.10	3	mA	
		Deep software standby mode		-	20	60	µA	
Analog power supply current	During 12-bit A/D conversion (when a sample-and-hold circuit is in use; per unit)		AI_{CC0}	-	3	5	mA	
	During 12-bit A/D conversion (when a sample-and-hold circuit is not in use; per unit)			-	3	5	mA	
	Programmable gain amp (per channel)			-	1	2	mA	
	Window comparator (1 channel)				0.5	1	mA	
	Window comparator (6 channels)			-	1	2	mA	
	During 12-bit A/D conversion (per unit)			-	60	90	µA	
	During 10-bit A/D conversion (per unit)		AI_{CC}	-	0.9	2	mA	
	Waiting for 10-bit A/D conversion (all units)			-	0.3	3	µA	
Reference power supply current	During 12-bit A/D conversion (per unit)		AI_{REFH0}	-	1.6	3	mA	
	Waiting for 12-bit A/D conversion (all units)			-	1.6	3	mA	
	During 10-bit A/D conversion (per unit)		AI_{REF}	-	0.1	1	mA	
	Waiting for 10-bit A/D conversion (all units)			-	0.1	3	µA	
VCC rising gradient			SV_{CC}	-	-	20	ms/V	

Note 1. Supply current values are with all output pins unloaded.
Note 2. Measured with clocks supplied to the peripheral functions. This does not include the BGO operation.
Note 3. I_{CC} depends on f (ICLK) as follows. (ICLK: PCLK = 8:4)
ICC max. = 0.54 x f + 16 (max.)
ICC max. = 0.14 x f + 6 (normal operation)
ICC max. = 0.44 x f + 16 (sleep mode)
Note 4. Measured with clocks not supplied to the peripheral functions. This does not include the BGO operation.
Note 5. Incremented if data is written to or erased from the ROM or data flash for data storage during the program execution.
Note 6. The values are for reference.

Table 33.4 Permissible Output Currents

Note: Items for which test conditions are not specifically stated in the table below have the same values under conditions 1 to 3.

Condition 1: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 3.0 to 3.6 V, VREFH0 = 3.0 V to AVCC0, VREF = 3.0 V to AVCC

Condition 2: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC

Condition 3: VCC = PLLVCC = 4.0 to 5.5 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC
Ta = -40 to +85°C. Ta is the same under conditions 1 to 3.

Item	Symbol	Min.	Typ.	Max.	Unit
Permissible output low current (average value per pin)	I_{OL}	-	-	2.0*1	mA
Permissible output low current (max. value per pin)	I_{OL}	-	-	4.0*1	mA
Permissible output low current (total)	ΣI_{OL}	-	-	110	mA
Permissible output high current (average value per pin)	$-I_{OH}$	-	-	2.0*1	mA
Permissible output high current (max. value per pin)	$-I_{OH}$	-	-	4.0*1	mA
Permissible output high current (total)	$\Sigma -I_{OH}$	-	-	35	mA

Caution: To protect the LSI's reliability, the output current values should not exceed the permissible output current.

Note 1. I_{OL} = 15 mA (max.)/ $-I_{OH}$ = 5 mA (max.) for P71 to P76 and P90 to P95. Note, however, that up to 6 (112-pin or 100-pin LQFP) or 3 (80-pin or 64-pin LQFP) pins can accept over 2.0-mA I_{OL} / $-I_{OH}$ at the same time.

33.3 AC Characteristics

Table 33.5 Operation Frequency Value

Note:Items for which test conditions are not specifically stated in the table below have the same values under conditions 1 to 3.

Condition 1: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 3.0 to 3.6 V, VREFH0 = 3.0 V to AVCC0, VREF = 3.0 V to AVCC

Condition 2: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC

Condition 3: VCC = PLLVCC = 4.0 to 5.5 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC
Ta = -40 to +85°C. Ta is the same under conditions 1 to 3.

Item		Symbol	Min.	Typ.	Max.	Unit
Operating frequency	System clock (ICLK)	f	8	-	100	MHz
	Peripheral module clock (PCLK)		8	-	50	

33.3.1 Clock Timing

Table 33.6 Clock Timing

Note:Items for which test conditions are not specifically stated in the table below have the same values under conditions 1 to 3.

Condition 1: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 3.0 to 3.6 V, VREFH0 = 3.0 V to AVCC0, VREF = 3.0 V to AVCC
Condition 2: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC
Condition 3: VCC = PLLVCC = 4.0 to 5.5 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC
Ta = –40 to +85°C. Ta is the same under conditions 1 to 3.

Item	Symbol	Min.	Max.	Unit	Test Conditions
Oscillation settling time after reset (crystal)	t_{OSC1}	10	-	ms	Figure 33.1
Oscillation settling time after leaving software standby mode (crystal)	t_{OSC2}	10	-	ms	Figure 33.2
Oscillation settling time after leaving deep software standby mode (crystal)	t_{OSC3}	10	-	ms	Figure 33.3
EXTAL external clock output delay settling time	t_{DEXT}	1	-	ms	Figure 33.1
EXTAL external clock input low pulse width	t_{EXL}	35	-	ns	Figure 33.4
EXTAL external clock input high pulse width	t_{EXH}	35	-	ns	
EXTAL external clock rising time	t_{EXr}	-	5	ns	
EXTAL external clock falling time	t_{EXf}	-	5	ns	
On-chip oscillator (IWDTCLK) oscillation frequency	$f_{IWDTCLK}$	62.5	187.5	kHz	

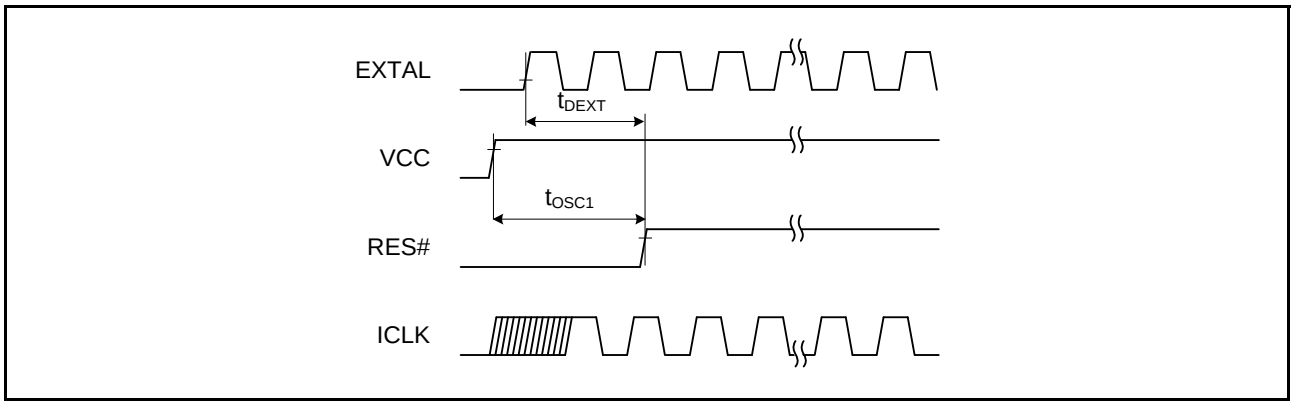


Figure 33.1 Oscillation Settling Timing

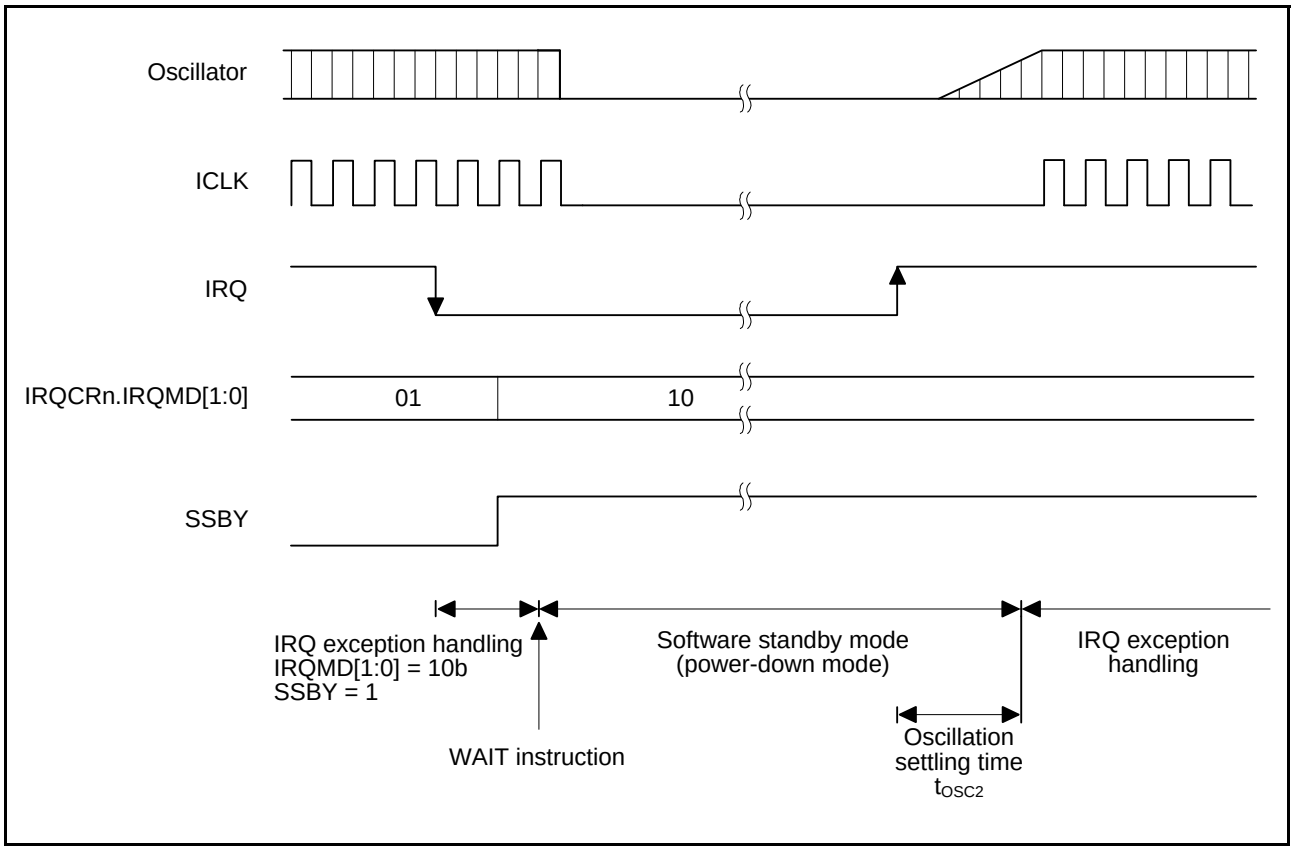


Figure 33.2 Oscillation Settling Timing after Software Standby Mode

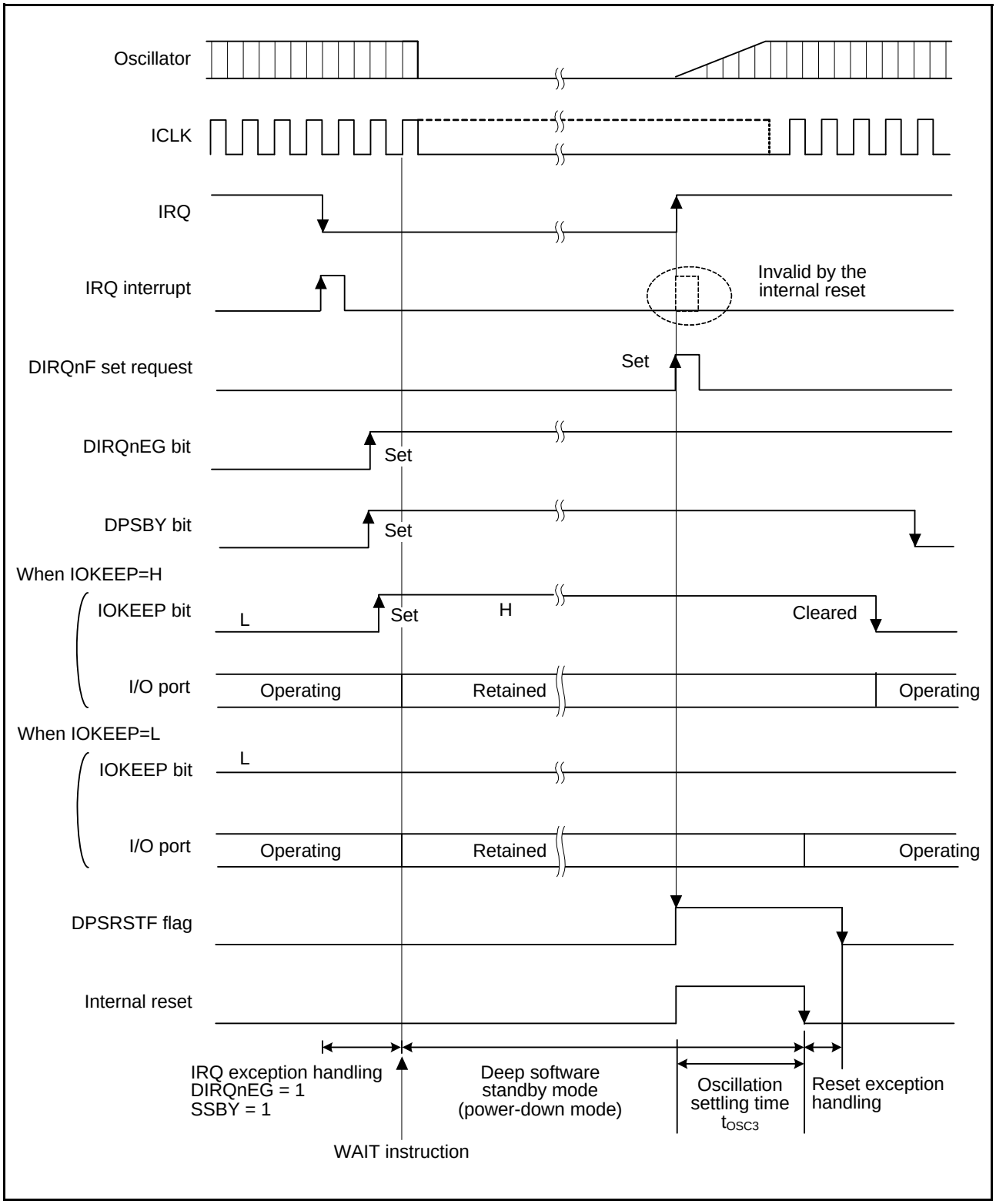


Figure 33.3 Oscillation Settling Timing after Deep Software Standby Mode

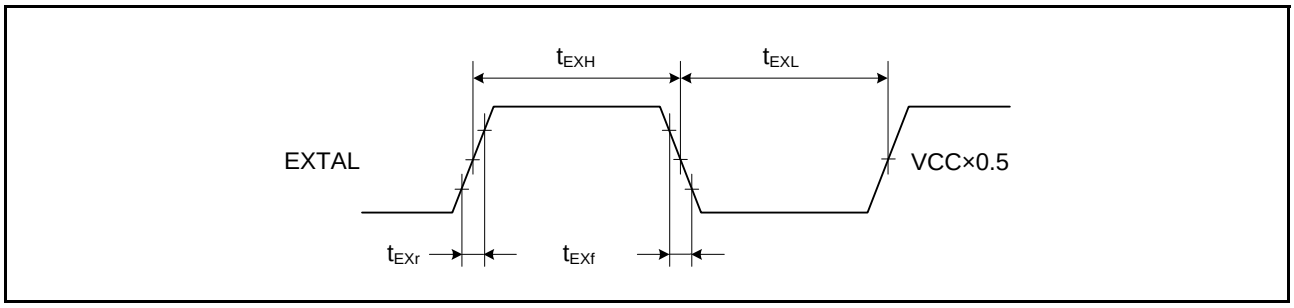


Figure 33.4 EXTAL External Input Clock Timing

33.3.2 Control Signal Timing

Table 33.7 Control Signal Timing

Note:Items for which test conditions are not specifically stated in the table below have the same values under conditions 1 to 3.

Condition 1: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 3.0 to 3.6 V, VREFH0 = 3.0 V to AVCC0, VREF = 3.0 V to AVCC

Condition 2: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC

Condition 3: VCC = PLLVCC = 4.0 to 5.5 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC
Ta = –40 to +85°C. Ta is the same under conditions 1 to 3.

Item	Symbol	Min.	Max.	Unit	Test Conditions
RES# pulse width (except for programming or erasure of the ROM or data-flash memory or blank checking of the data-flash memory*1)	t_{RESW}*2	20	-	t_{Icyc}*4	Figure 33.5
		1.5	-	µs	
Internal reset time*3	t_{RESW2}	35	-	µs	
NMI pulse width	t_{NMIW}	200	-	ns	Figure 33.6
IRQ pulse width	t_{IRQW}	200	-	ns	Figure 33.7

Note 1. For a reset by the signal on the RES# pin during programming or erasure of the ROM or data-flash memory or during blank checking of the data-flash memory, see section 31.12, Usage Notes in section 31, ROM (Flash Memory for Code Storage).
Note 2. Both the time and the number of cycles should satisfy the specifications.
Note 3. This is to specify the FCU reset.
Note 4. ICLK cycles.

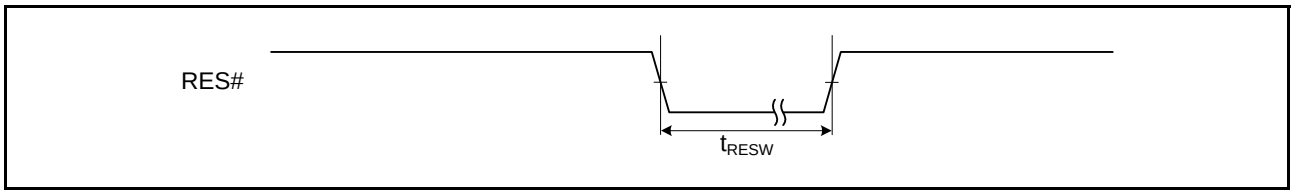


Figure 33.5 Reset Input Timing

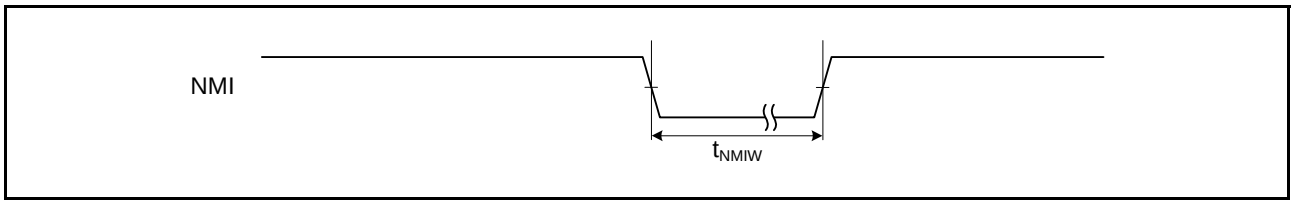


Figure 33.6 NMI Interrupt Input Timing

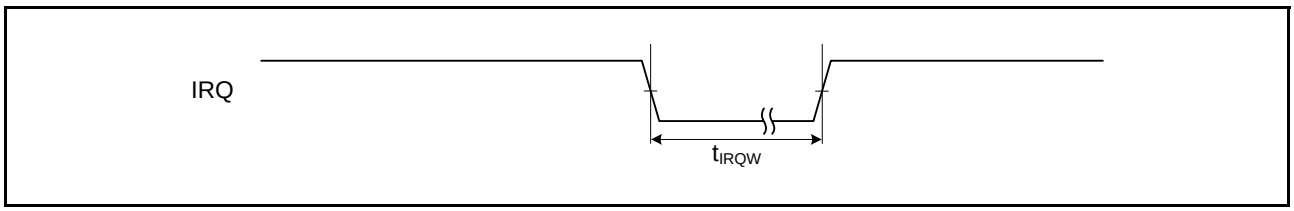


Figure 33.7 IRQ Interrupt Input Timing

33.3.3 Timing of On-Chip Peripheral Modules

Table 33.8 Timing of On-Chip Peripheral Modules (1)

Note:Items for which test conditions are not specifically stated in the table below have the same values under conditions 1 to 3.

Condition 1: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 3.0 to 3.6 V, VREFH0 = 3.0 V to AVCC0, VREF = 3.0 V to AVCC

Condition 2: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC

Condition 3: VCC = PLLVCC = 4.0 to 5.5 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC
Ta = –40 to +85°C. Ta is the same under conditions 1 to 3.

Item			Symbol	Min.	Typ.	Max.	Unit
SCI	Input clock cycle	Asynchronous	t_{Scyc}	$4 \times t_{Pcyc}$	-	ns	Figure 33.8
		Clock synchronous		$6 \times t_{Pcyc}$	-		
	Input clock pulse width		t_{SCKW}	$0.4 \times t_{Pcyc}$	$0.6 \times t_{Scyc}$	ns	
	Input clock rise time		t_{SCKr}	-	20	ns	
	Input clock fall time		t_{SCKf}	-	20	ns	
	Output clock cycle	Asynchronous	t_{Scyc}	$16 \times t_{Pcyc}$	-	ns	
		Clock synchronous		$6 \times t_{Pcyc}$	-	ns	
	Output clock pulse width		t_{SCKW}	$0.4 \times t_{Scyc}$	$0.6 \times t_{Scyc}$	ns	
	Output clock rise time		t_{SCKr}	-	20	ns	
	Output clock fall time		t_{SCKf}	-	20	ns	
	Transmit data delay time (clock synchronous)		t_{TXD}	-	40	ns	Figure 33.9
	Receive data setup time (clock synchronous)		t_{RXS}	40	-	ns	
	Receive data hold time (clock synchronous)		t_{RXH}	40	-	ns	

Note: • t_{Pcyc}: PCLK cycle

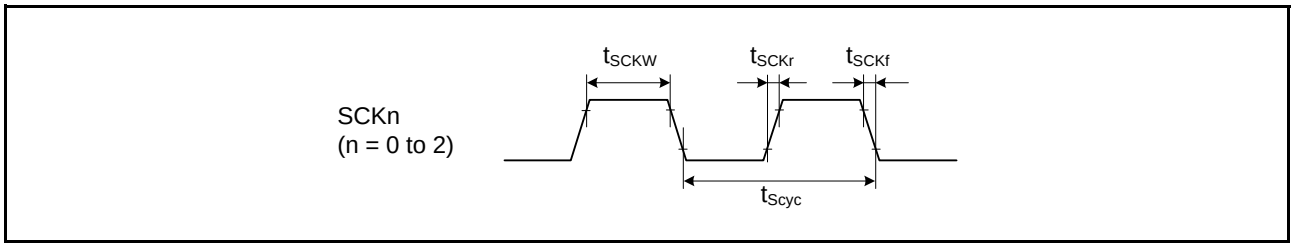


Figure 33.8 SCK Clock Input Timing

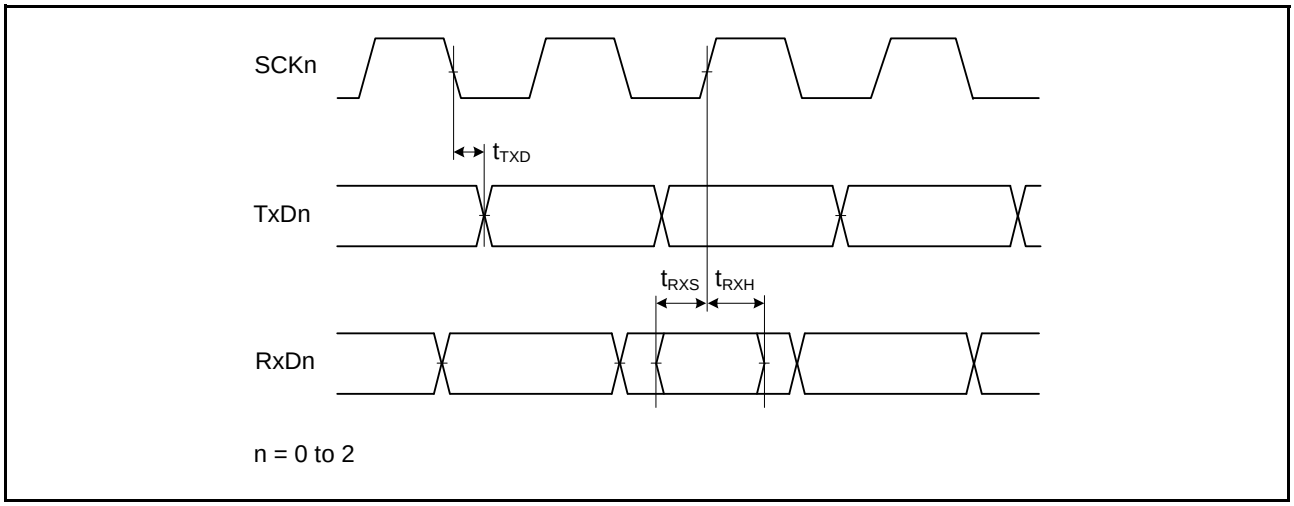


Figure 33.9 SCI Input/Output Timing: Clock Synchronous Mode

Table 33.9 Timing of On-Chip Peripheral Modules (2)

Note:Items for which test conditions are not specifically stated in the table below have the same values under conditions 1 to 3.

Condition 1: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 3.0 to 3.6 V, VREFH0 = 3.0 V to AVCC0, VREF = 3.0 V to AVCC

Condition 2: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC

Condition 3: VCC = PLLVCC = 4.0 to 5.5 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC
Ta = –40 to +85°C. Ta is the same under conditions 1 to 3.

Item		Symbol	Min.*1 *2	Max.	Unit	Test Conditions
RIIC (standard mode)	SCL input cycle time	t_{SCL}	6(12) × t_{IICcyc} + 1300	-	ns	Figure 33.10
	SCL input high pulse width	t_{SCLH}	3(6) × t_{IICcyc} + 300	-	ns	
	SCL input low pulse width	t_{SCLL}	3(6) × t_{IICcyc} + 1000	-	ns	
	SCL, SDA input rising time	t_{Sr}	-	1000	ns	
	SCL, SDA input falling time	t_{Sf}	-	300	ns	
	SCL, SDA input spike pulse removal time	t_{SP}	0	1(4) × t_{IICcyc}	ns	
	SDA input bus free time	t_{BUF}	3(6) × t_{IICcyc} + 300	-	ns	
	Start condition input hold time	t_{STAH}	t_{IICcyc} + 300	-	ns	
	Re-start condition input setup time	t_{STAS}	1000	-	ns	
	Stop condition input setup time	t_{STOS}	1000	-	ns	
	Data input setup time	t_{SDAS}	t_{IICcyc} + 50	-	ns	
	Data input hold time	t_{SDAH}	0	-	ns	
	SCL, SDA capacitive load	C_b	-	400	pF	
RIIC (fast mode)	SCL input cycle time	t_{SCL}	6(12) × t_{IICcyc} + 600	-	ns	
	SCL input high pulse width	t_{SCLH}	3(6) × t_{IICcyc} + 300	-	ns	
	SCL input low pulse width	t_{SCLL}	3(6) × t_{IICcyc} + 300	-	ns	
	SCL, SDA input rising time	t_{Sr}	20 + 0.1C_b	300	ns	
	SCL, SDA input falling time	t_{Sf}	20 + 0.1C_b	300	ns	
	SCL, SDA input spike pulse removal time	t_{SP}	0	1(4) × t_{IICcyc}	ns	
	SDA input bus free time	t_{BUF}	3(6) × t_{IICcyc} + 300	-	ns	
	Start condition input hold time	t_{STAH}	t_{IICcyc} + 300	-	ns	
	Re-start condition input setup time	t_{STAS}	300	-	ns	
	Stop condition input setup time	t_{STOS}	300	-	ns	
	Data input setup time	t_{SDAS}	t_{IICcyc} + 50	-	ns	
	Data input hold time	t_{SDAH}	0	-	ns	
	SCL, SDA capacitive load	C_b	-	400	pF	

Note: • t_{IICcyc}: Cycles of internal base clock (IICφ) for the RIIC module
Note 1. The value in parentheses is used when ICMR3.NF[1:0] are set to 11b while a digital filter is enabled with ICFER.NFE = 1.
Note 2. Cb indicates the total capacity of the bus line.

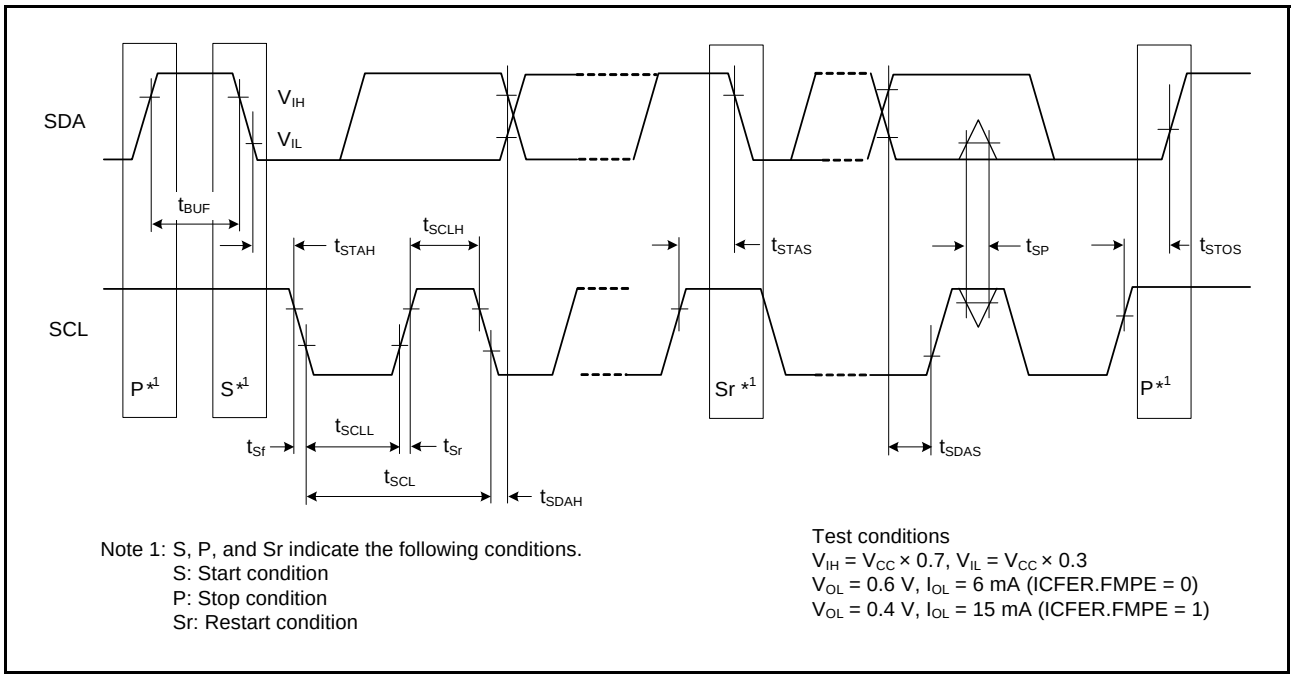


Figure 33.10 I2C Bus Interface Input/Output Timing

Table 33.10 Timing of On-Chip Peripheral Modules (3)

Note:Items for which test conditions are not specifically stated in the table below have the same values under conditions 1 to 3.

Condition 1: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 3.0 to 3.6 V, VREFH0 = 3.0 V to AVCC0, VREF = 3.0 V to AVCC

Condition 2: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC

Condition 3: VCC = PLLVCC = 4.0 to 5.5 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC
Ta = –40 to +85°C. Ta is the same under conditions 1 to 3.

Item			Symbol	Min.	Max.	Unit	Test Conditions
RSPI	RSPCK clock cycle	Master	t_{SPcyc}	4	4096	t_{Pcyc}	Figure 33.11
		Slave		8	4096		
	RSPCK clock high pulse width	Master	t_{SPCKWH}	(t_{Spcyc} - t_{SPCKR} - t_{SPCKF}) / 2-3	-	ns	
		Slave		(t_{Spcyc} - t_{SPCKR} - t_{SPCKF}) / 2	-		
	RSPCK clock low pulse width	Master	t_{SPCKWL}	(t_{Spcyc} - t_{SPCKR} - t_{SPCKF}) / 2-3	-	ns	
		Slave		(t_{Spcyc} - t_{SPCKR} - t_{SPCKF}) / 2	-		
	RSPCK clock rise/fall time	Output	t_{SPCKR} t_{SPCKF}	-	5	ns	
		Input		-	1	µs	
	Data input setup time	Master	t_{SU}	25	-	ns	Figure 33.12 to Figure 33.15
		Slave		0	-		
	Data input hold time	Master	t_H	0	-	ns	
		Slave		20+2×t_{Pcyc}	-		
	SSL setup time	Master	t_{LEAD}	1	8	t_{SPcyc}	
		Slave		4	-	t_{Pcyc}	
	SSL hold time	Master	t_{LAG}	1	8	t_{SPcyc}	
		Slave		4	-	t_{Pcyc}	
	Data output delay time	Master	t_{OD}	-	20	ns	
		Slave		-	3×t_{Pcyc} +40		
	Data output hold time	Master	t_{OH}	0	-	ns	
		Slave		0	-		
	Successive transmission delay time	Master	t_{TD}	t_{SPcyc}+2×t_{Pcyc}	8×t_{SPcyc} +2×t_{Pcyc}	ns	
		Slave		4×t_{Pcyc}	-		
	MOSI, MISO rise/fall time	Output	t_{DR} t_{DF}	-	15	ns	Figure 33.12 to Figure 33.15
		Input		-	1	µs	
	SSL rise/fall time	Output	t_{SSLR} t_{SSLF}	-	15	ns	
		Input		-	1	µs	
	Slave access time		t_{SA}	-	4	t_{Pcyc}	Figure 33.12 to Figure 33.15
	Slave output release time		t_{REL}	-	3	t_{Pcyc}	

Note: • Note 1: t_{Pcyc}: PCLK cycle

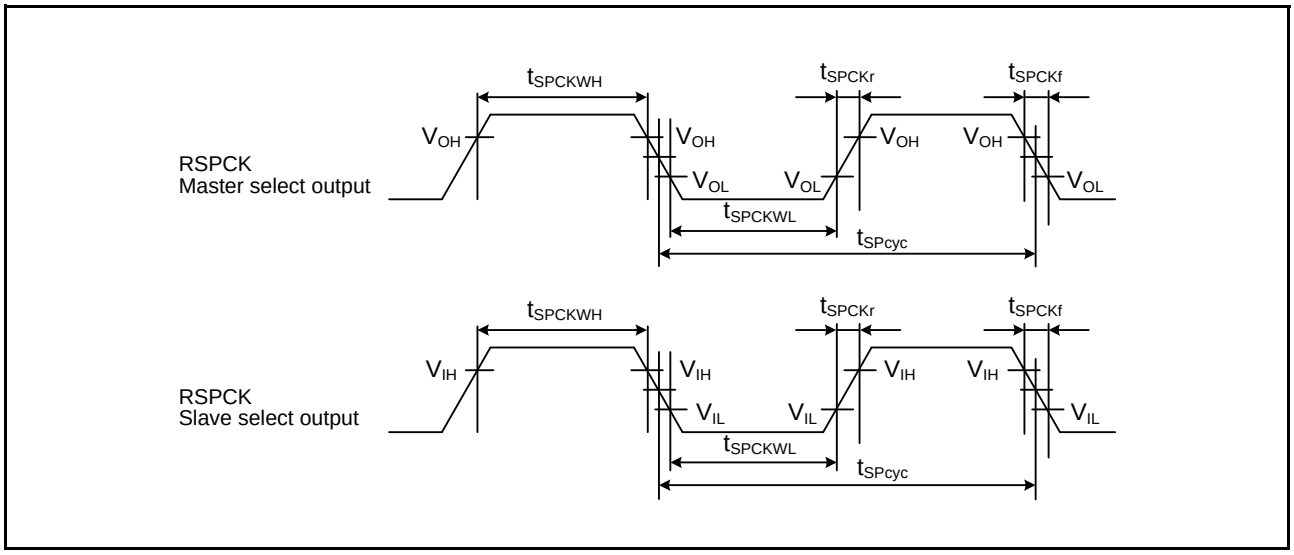


Figure 33.11 RSPI Clock Timing

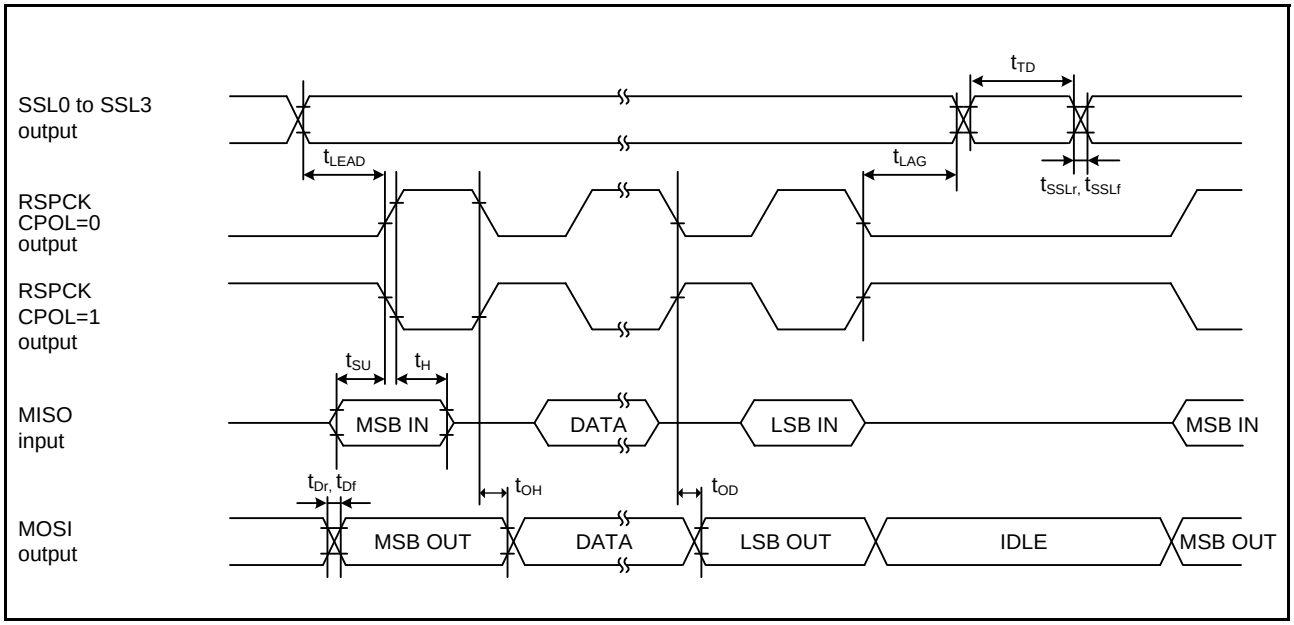


Figure 33.12 RSPI Timing (Master, CPHA = 0)

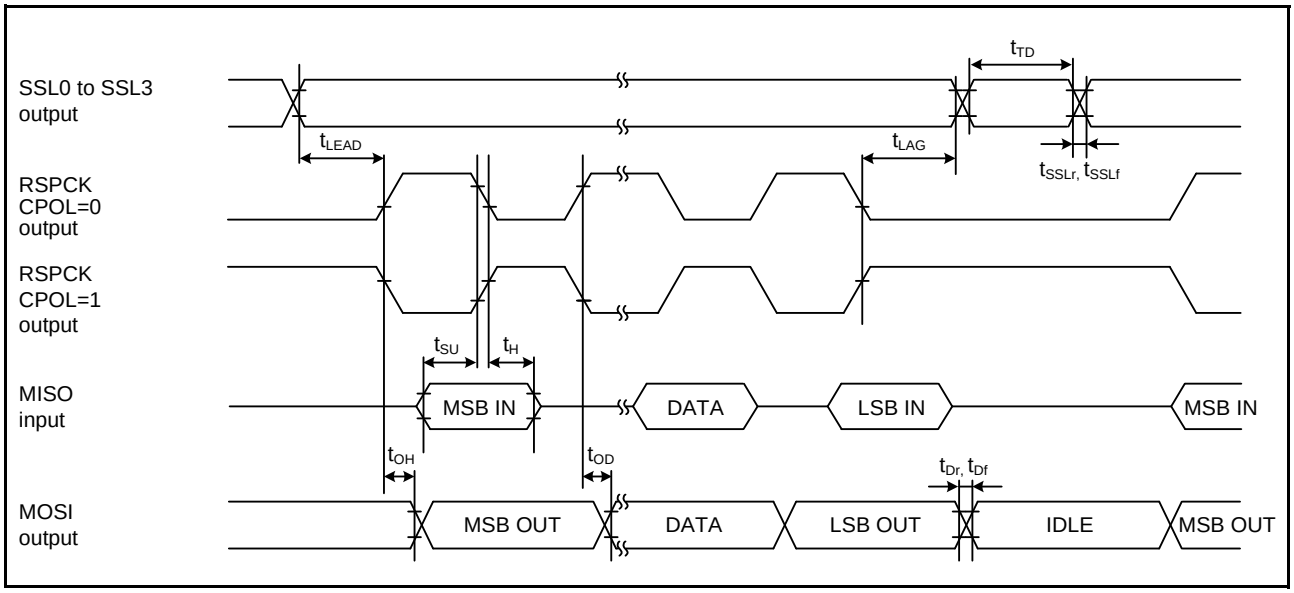


Figure 33.13 RSPI Timing (Master, CPHA = 1)

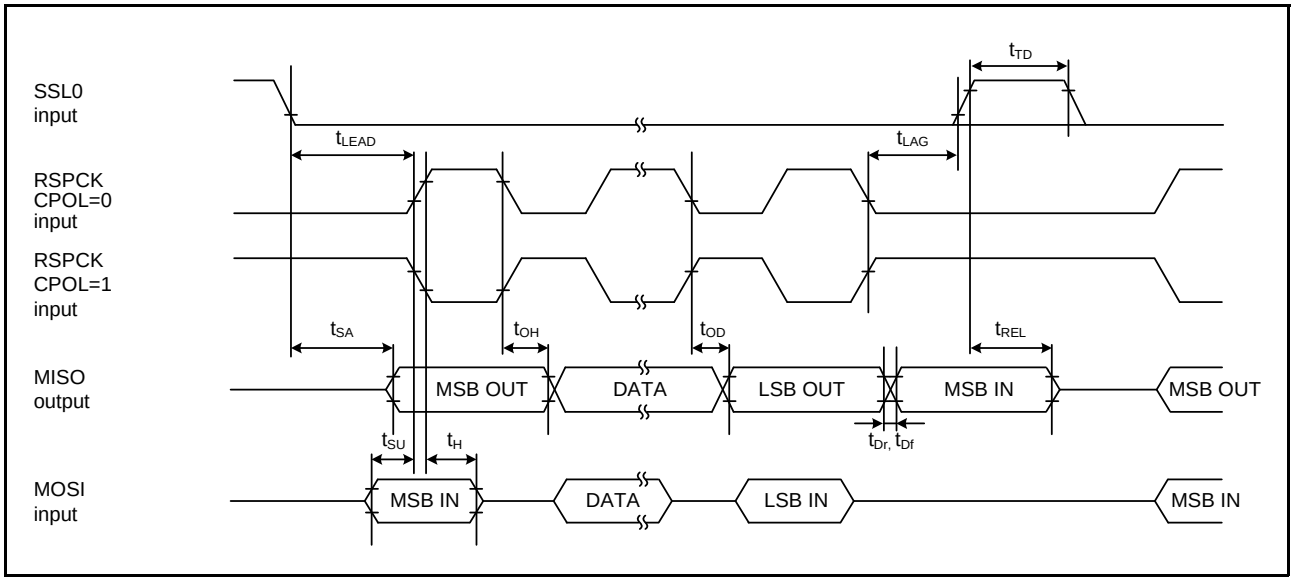


Figure 33.14 RSPI Timing (Slave, CPHA = 0)

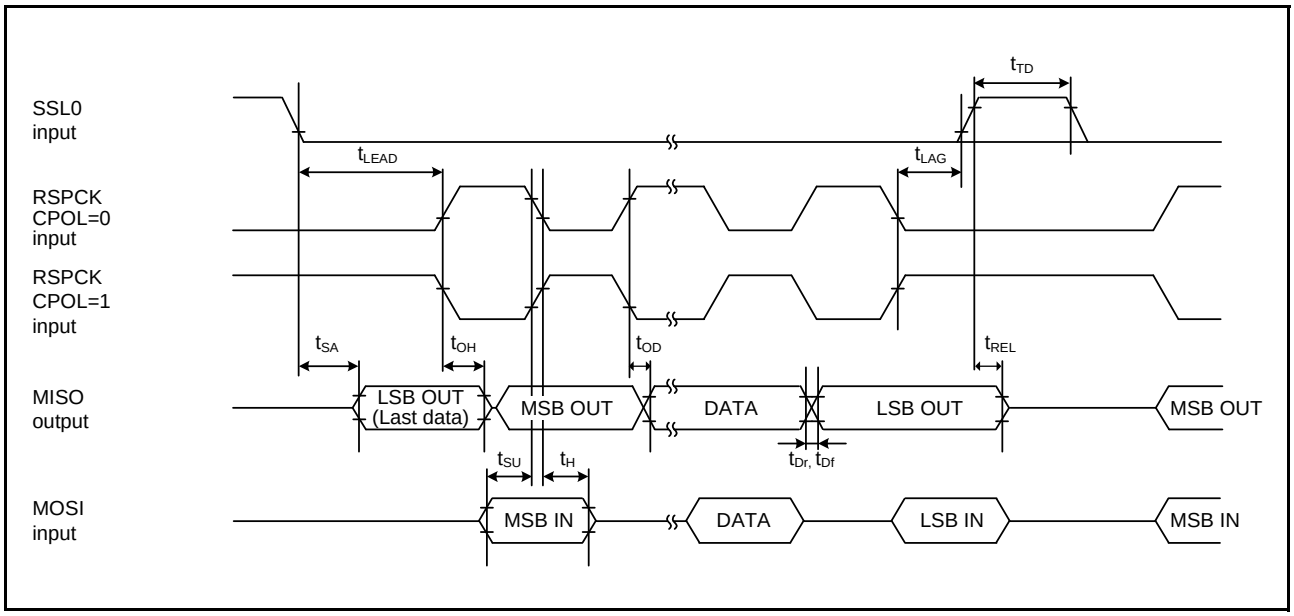


Figure 33.15 RSPI Timing (Slave, CPHA = 1)

Table 33.11 Timing of On-Chip Peripheral Modules (4)

Note:Items for which test conditions are not specifically stated in the table below have the same values under conditions 1 to 3.

Condition 1: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 3.0 to 3.6 V, VREFH0 = 3.0 V to AVCC0, VREF = 3.0 V to AVCC

Condition 2: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC

Condition 3: VCC = PLLVCC = 4.0 to 5.5 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC
Ta = –40 to +85°C. Ta is the same under conditions 1 to 3.

Item		Symbol	Min.	Max.	Unit	Test Conditions
MTU3	Input capture input pulse width (single-edge setting)	t_{TICW}	3.0	-	t_{Icyc}	Figure 33.16
	Input capture input pulse width (both-edge setting)	t_{TICW}	5.0	-	t_{Icyc}	
	Timer clock pulse width (single-edge setting)	$t_{TCKWH/L}$	3.0	-	t_{Icyc}	Figure 33.17
	Timer clock pulse width (both-edge setting)	$t_{TCKWH/L}$	5.0	-	t_{Icyc}	
	Timer clock pulse width (phase coefficient mode)	$t_{TCKWH/L}$	5.0	-	t_{Icyc}	
GPT	Input capture input pulse width (single-edge setting)	t_{GTICW}	3.0	-	t_{Icyc}	Figure 33.18
	Input capture input pulse width (both-edge setting)	t_{GTICW}	5.0	-	t_{Icyc}	

Note: • t_{Icyc}: ICLK cycle

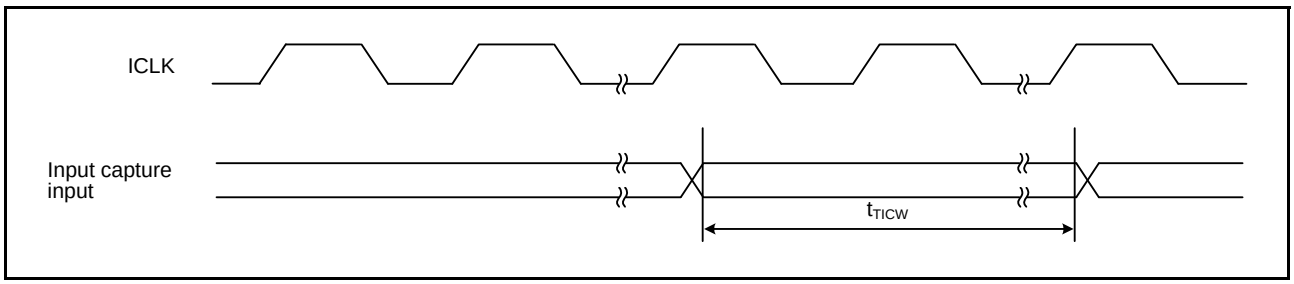


Figure 33.16 MTU3 Input/Output Timing

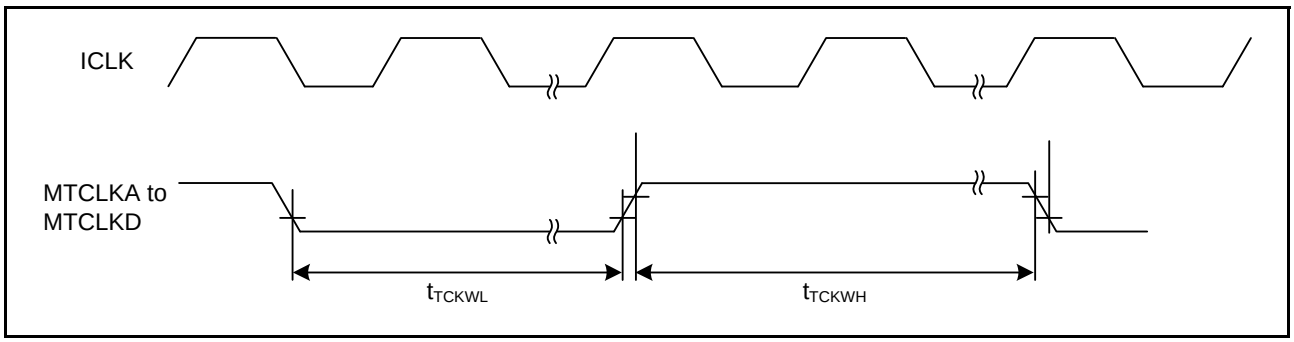


Figure 33.17 MTU3 Clock Input Timing

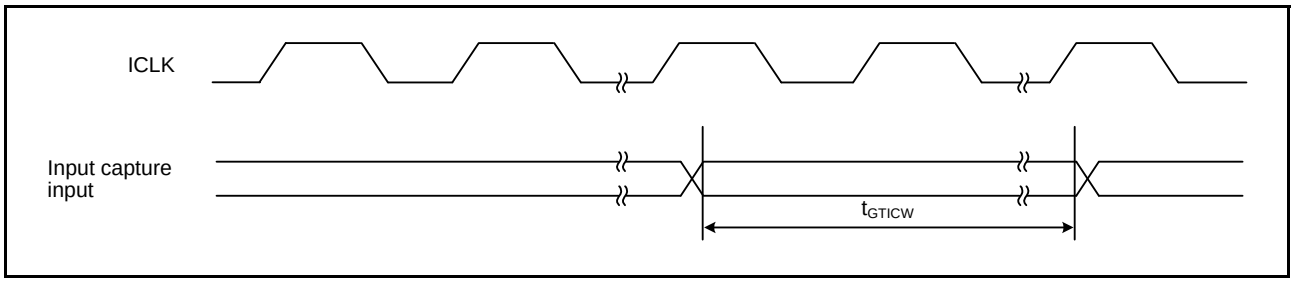


Figure 33.18 GPT Input/Output Timing

Table 33.12 Timing of On-Chip Peripheral Modules (5)

Note:Items for which test conditions are not specifically stated in the table below have the same values under conditions 1 to 3.

Condition 1: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 3.0 to 3.6 V, VREFH0 = 3.0 V to AVCC0, VREF = 3.0 V to AVCC

Condition 2: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC

Condition 3: VCC = PLLVCC = 4.0 to 5.5 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC
Ta = -40 to +85°C. Ta is the same under conditions 1 to 3.

Item		Symbol	Min.	Max.	Unit	Test Conditions
POE3	POE# input pulse width	t_{POEW}	1.5	-	t_{Pcyc}	Figure 33.19

Note: • t_{Pcyc}: PCLK cycle

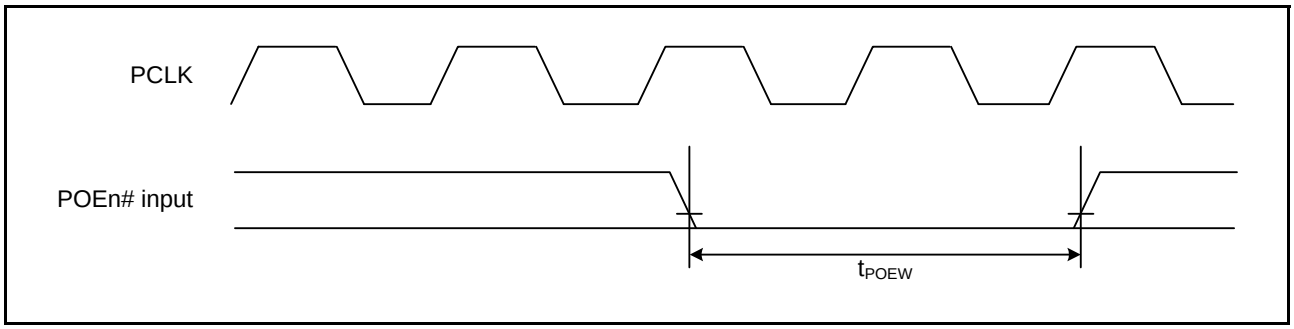


Figure 33.19 POE3# Clock Timing

33.4 A/D Conversion Characteristics

Table 33.13 10-Bit A/D Conversion Characteristics

Note:Items for which test conditions are not specifically stated in the table below have the same values under conditions 1 to 3.

Condition 1: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 3.0 to 3.6 V, VREFH0 = 3.0 V to AVCC0, VREF = 3.0 V to AVCC
Ta = -40 to +85°C

Item	Min.	Typ.	Max.	Unit	Test Conditions
Resolution	10	10	10	Bit	
Conversion time*1 (AD clock = 25-MHz operation)	2.0	-	-	μs	Sampling 25 states
Analog input capacitance	-	-	4	pF	
Integral nonlinearity error	-	-	±3.0	LSB	
Offset error	-	-	±3.0	LSB	
Full-scale error	-	-	±3.0	LSB	
Quantization error	-	±0.5	-	LSB	
Absolute accuracy	-	-	±4.0	LSB	
Permissible signal source impedance	-	-	1.0	kΩ	

Condition 2: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC

Condition 3: VCC = PLLVCC = 4.0 to 5.5 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC
Ta = -40 to +85°C. Ta is the same under conditions 1 to 3.

Item	Min.	Typ.	Max.	Unit	Test Conditions
Resolution	10	10	10	Bit	
Conversion time*1 (AD clock = 50-MHz operation)	1.0	-	-	μs	Sampling 25 states
Analog input capacitance	-	-	4	pF	
Integral nonlinearity error	-	-	±3.0	LSB	
Offset error	-	-	±3.0	LSB	
Full-scale error	-	-	±3.0	LSB	
Quantization error	-	±0.5	-	LSB	
Absolute accuracy	-	-	±4.0	LSB	
Permissible signal source impedance	-	-	1.0	kΩ	

Note 1. The conversion time includes the sampling time and the comparison time. As the test conditions, the number of sampling states is indicated.

Table 33.14 12-Bit A/D Conversion Characteristics

Note:Items for which test conditions are not specifically stated in the table below have the same values under conditions 1 to 3.

Condition 1: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 3.0 to 3.6 V, VREFH0 = 3.0 V to AVCC0, VREF = 3.0 V to AVCC
Ta = -40 to +85°C, ICLK = 8 to 100 MHz, PCLK = 8 to 50 MHz

Item		Min.	Typ.	Max.	Unit	Test Conditions
Resolution		12	12	12	Bit	
Conversion time*1 (AD clock = 25-MHz operation)		2.0	-	-	µs	Sampling 20 states
Analog input capacitance		-	-	6	pF	
Integral nonlinearity error		-	-	±4.0	LSB	
Offset error		-	-	±7.5	LSB	
Full-scale error		-	-	±7.5	LSB	
Quantization error		-	±0.5	-	LSB	
Absolute accuracy	When a sample-and-hold circuit is in use	-	-	±8.0	LSB	AVin = 0.25 to AV_{REFH} - 0.25
	When a sample-and-hold circuit is not in use	-	-	±8.0	LSB	AVin = AV_{REFL} to AV_{REFH}
Permissible signal source impedance		-	-	3.0	kΩ	

Condition 2: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC

Condition 3: VCC = PLLVCC = 4.0 to 5.5 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC
Ta = -40 to +85°C. Ta is the same under conditions 1 to 3. ICLK = 8 to 100 MHz, PCLK = 8 to 50 MHz.

Item		Min.	Typ.	Max.	Unit	Test Conditions
Resolution		12	12	12	Bit	
Conversion time*1 (AD clock = 25-MHz operation)		1.0	-	-	µs	Sampling 20 states
Analog input capacitance		-	-	6	pF	
Integral nonlinearity error		-	-	±4.0	LSB	
Offset error		-	-	±7.5	LSB	
Full-scale error		-	-	±7.5	LSB	
Quantization error		-	±0.5	-	LSB	
Absolute accuracy	When a sample-and-hold circuit is in use	-	-	±8.0	LSB	AVin = 0.25 to AV_{REFH} - 0.25
	When a sample-and-hold circuit is not in use	-	-	±8.0	LSB	AVin = AV_{REFL} to AV_{REFH}
Permissible signal source impedance		-	-	3.0	kΩ	

Note 1. The conversion time includes the sampling time and the comparison time. As the test conditions, the number of sampling states is indicated.

Table 33.15 Programmable Gain Amp Characteristics

Note:Items for which test conditions are not specifically stated in the table below have the same values under conditions 1 to 3.

Condition 1: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 3.0 to 3.6 V, VREFH0 = 3.0 V to AVCC0, VREF = 3.0 V to AVCC

Condition 2: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC

Condition 3: VCC = PLLVCC = 4.0 to 5.5 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC
Ta = -40 to +85°C. Ta is the same under conditions 1 to 3.

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Analog input capacitance		Cin	-	-	6	pF	
Input offset voltage		Voff	-	-	8	mV	
Input voltage range (Vin)	Gain × 2.000	Vin	0.050 x AVcc	-	0.38 x AVcc	V	
	Gain × 2.500		0.047 x AVcc	-	0.30 x AVcc		
	Gain × 3.077		0.045 x AVcc	-	0.24 x AVcc		
	Gain × 3.636		0.042 x AVcc	-	0.21 x AVcc		
	Gain × 4.000		0.040 x AVcc	-	0.19 x AVcc		
	Gain × 4.444		0.036 x AVcc	-	0.17 x AVcc		
	Gain × 5.000		0.033 x AVcc	-	0.15 x AVcc		
	Gain × 5.714		0.031 x AVcc	-	0.13 x AVcc		
	Gain × 6.667		0.029 x AVcc	-	0.11 x AVcc		
	Gain × 10.000		0.025 x AVcc	-	0.08 x AVcc		
	Gain × 13.333		0.023 x AVcc	-	0.06 x AVcc		
Slew rate		SR	10	-	-	V/µs	
Gain error	Gain × 2.000	-	-	-	1	%	
	Gain × 2.500		-	-	1		
	Gain × 3.077		-	-	1		
	Gain × 3.636		-	-	1.5		
	Gain × 4.000		-	-	1.5		
	Gain × 4.444		-	-	2		
	Gain × 5.000		-	-	2		
	Gain × 5.714		-	-	2		
	Gain × 6.667		-	-	3		
	Gain × 10.000		-	-	4		
	Gain × 13.333		-	-	4		

Table 33.16 Comparator Characteristics

Note:Items for which test conditions are not specifically stated in the table below have the same values under conditions 1 to 3.

Condition 1: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 3.0 to 3.6 V, VREFH0 = 3.0 V to AVCC0, VREF = 3.0 V to AVCC
Condition 2: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC
Condition 3: VCC = PLLVCC = 4.0 to 5.5 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC
Ta = -40 to +85°C. Ta is the same under conditions 1 to 3.

Item	Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Analog input capacitance	Cin	-	-	6	pF	
REFH pin offset voltage	Voff	-	-	5	mV	
REFL pin offset voltage		-	-	5	mV	
REFH input voltage range	Vin	1.7	-	AVcc – 0.3	V	
REFL input voltage range		0.3	-	AVcc – 1.7	V	
REFH reply time	tCR	-	-	1	µs	
REFL reply time	tCF	-	-	1	µs	

33.5 Power-on Reset Circuit, Voltage Detection Circuit Characteristics

Table 33.17 Power-on Reset Circuit, Voltage Detection Circuit Characteristics

Note:Items for which test conditions are not specifically stated in the table below have the same values under conditions 1 to 3.

Condition 1: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 3.0 to 3.6 V, VREFH0 = 3.0 V to AVCC0, VREF = 3.0 V to AVCC

Condition 2: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC
Ta = -40 to +85°C. Ta is the same under conditions 1 to 3.

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Voltage detection level	Power-on reset (POR)	V_{POR}	2.48	2.60	2.72	V	Figure 33.20
	Voltage detection circuit (LVD)	Vdet1	2.68	2.80	2.92		Figure 33.21
		Vdet2	2.98	3.10	3.22		Figure 33.22
Internal reset time		t_{POR}	20	35	50	ms	Figure 33.21 and Figure 33.22
Min. VCC down time*1		t_{VOFF}	200	-	-	us	Figure 33.20 to Figure 33.22
Reply delay time		tdet	-	-	200	us	

Condition 3: VCC = PLLVCC = 4.0 to 5.5 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC
Ta = -40 to +85°C

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Voltage detection level	Power-on reset (POR)	V_{POR}	3.70	3.90	4.10	V	Figure 33.20
	Voltage detection circuit (LVD)	Vdet1	3.95	4.15	4.35		Figure 33.21
		Vdet2	4.40	4.60	4.80		Figure 33.22
Internal reset time		t_{POR}	20	35	50	ms	Figure 33.21 and Figure 33.22
Min. VCC down time*1		t_{VOFF}	200	-	-	us	Figure 33.20 to Figure 33.22
Reply delay time		tdet	-	-	200	us	

Note 1. The power-off time indicates the time when VCC is below the minimum value of voltage detection levels V_{POR}, V_{det1}, and V_{det2} for the POR/ LVD.

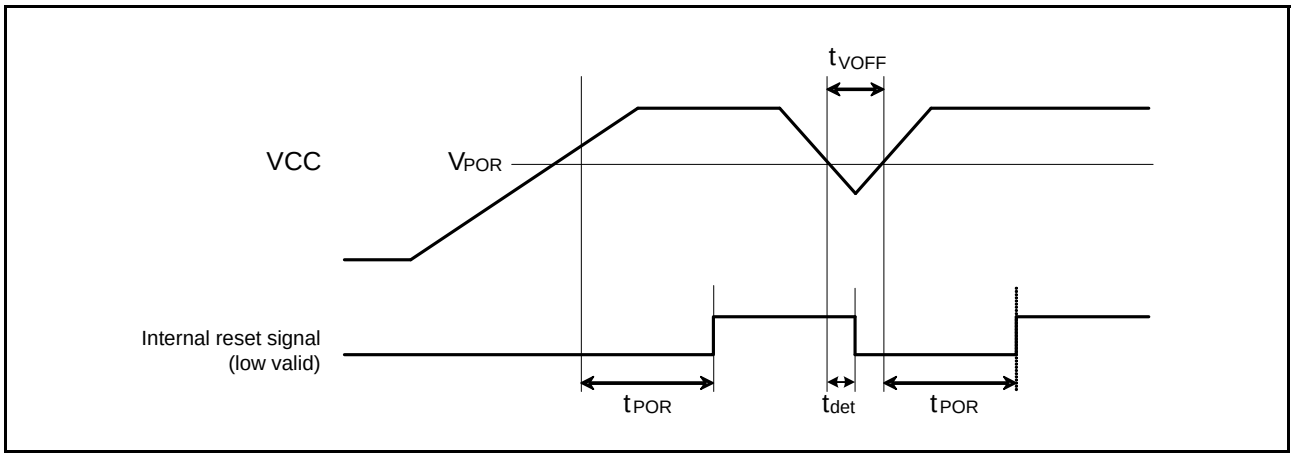


Figure 33.20 Power-on Reset Timing

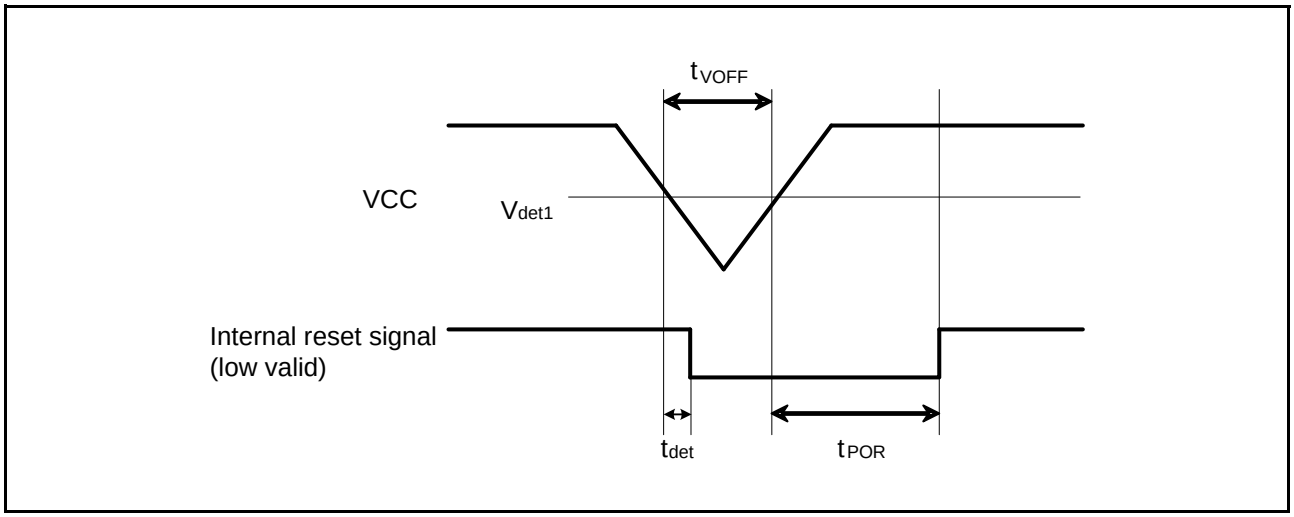


Figure 33.21 Voltage Detection Circuit Timing (Vdet1)

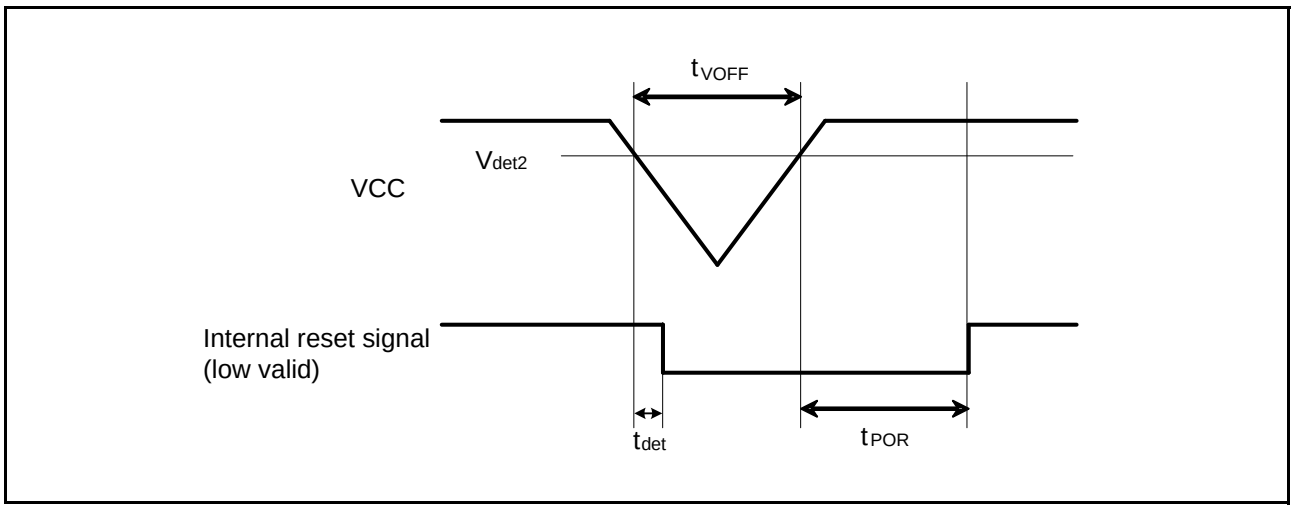


Figure 33.22 Voltage Detection Circuit Timing (Vdet2)

33.6 Oscillation Stop Detection Timing

Table 33.18 Oscillation Stop Detection Circuit Characteristics

Note:Items for which test conditions are not specifically stated in the table below have the same values under conditions 1 to 3.

Condition 1: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 3.0 to 3.6 V, VREFH0 = 3.0 V to AVCC0, VREF = 3.0 V to AVCC

Condition 2: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC

Condition 3: VCC = PLLVCC = 4.0 to 5.5 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC
Ta = -40 to +85°C. Ta is the same under conditions 1 to 3.

Item	Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Detection time	tdr	-	-	1.0	ms	Figure 33.23
Internal oscillation frequency when oscillation stop is detected	f_{MAIN}	0.5	-	7.0	MHz	

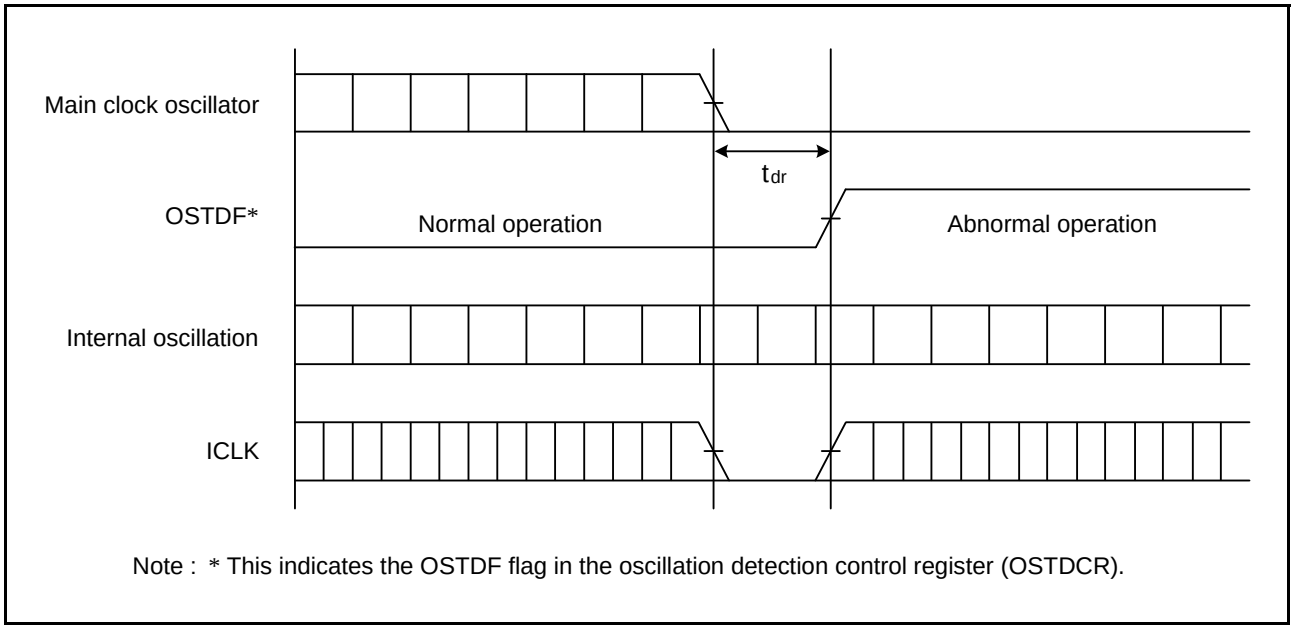


Figure 33.23 Oscillation Stop Detection Timing

33.7 ROM (Flash Memory for Code Storage) Characteristics

Table 33.19 ROM (Flash Memory for Code Storage) Characteristics

Note:Items for which test conditions are not specifically stated in the table below have the same values under conditions 1 to 3.

Condition 1: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 3.0 to 3.6 V, VREFH0 = 3.0 V to AVCC0, VREF = 3.0 V to AVCC

Condition 2: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC

Condition 3: VCC = PLLVCC = 4.0 to 5.5 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC
Temperature range for the programming/erasure operation:
Ta = -40 to +85°C. Ta is the same under conditions 1 to 3.

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Programming time	256 bytes	t_{P256}	-	2	12	ms	PCLK = 50 MHz $N_{PEC} \leq 100$
	4 Kbytes	t_{P4K}	-	23	50	ms	
	16 Kbytes	t_{P16K}	-	90	200	ms	
	256 byte	t_{P256}	-	2.4	14.4	ms	PCLK = 50 MHz $N_{PEC} > 100$
	4 Kbytes	t_{P4K}	-	27.6	60	ms	
	16 Kbytes	t_{P16K}	-	108	240	ms	
Erasure time	4 Kbytes	t_{E4K}	-	25	60	ms	PCLK = 50 MHz $N_{PEC} \leq 100$
	16 Kbytes	t_{E16K}	-	100	240	ms	
	4 Kbytes	t_{E4K}	-	30	72	ms	PCLK = 50 MHz $N_{PEC} > 100$
	16 Kbytes	t_{E16K}	-	120	288	ms	
Rewrite/erase cycle*1		N_{PEC}	1000*2	-	-	Times	
Suspend delay time during writing		t_{SPD}	-	-	120	µs	Figure 33.24 PCLK = 50 MHz
First suspend delay time during erasing (in suspend priority mode)		t_{SESD1}	-	-	120	µs	
Second suspend delay time during erasing (in suspend priority mode)		t_{SESD2}	-	-	1.7	ms	
Suspend delay time during erasing (in erasure priority mode)		t_{SEED}	-	-	1.7	ms	
Data hold time*3		t_{DRP}	10	-	-	Year	

Note 1. Definition of rewrite/erase cycle:
The rewrite/erase cycle is the number of erasing for each block. When the rewrite/erase cycle is n times (n = 1000), erasing can be performed n times for each block. For instance, when 256-byte writing is performed 16 times for different addresses in 4-Kbyte block and then the entire block is erased, the rewrite/erase cycle is counted as one. However, writing to the same address for several times as one erasing is not enabled (overwriting is prohibited).

Note 2. This indicates the minimum number that guarantees the characteristics after rewriting. (The guaranteed value is in the range from one to the minimum number.)

Note 3. This indicates the characteristic when rewrite is performed within the specification range including the minimum number.

33.8 Data Flash (Flash Memory for Data Storage) Characteristics

Table 33.20 Data Flash (Flash Memory for Data Storage) Characteristics

Note:Items for which test conditions are not specifically stated in the table below have the same values under conditions 1 to 3.

Condition 1: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 3.0 to 3.6 V, VREFH0 = 3.0 V to AVCC0, VREF = 3.0 V to AVCC

Condition 2: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC

Condition 3: VCC = PLLVCC = 4.0 to 5.5 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC
Temperature range for the programming/erasure operation:
Ta = -40 to +85°C. Ta is the same under conditions 1 to 3.

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Programming time	8 bytes	t_{DP8}	-	0.4	2	ms	PCLK = 50 MHz
	128 bytes	t_{DP128}	-	1	5	ms	
Erasure time	2 Kbytes	t_{DE2K}	-	70	250	ms	PCLK = 50 MHz
Blank check time	8 bytes	t_{DBC8}	-	-	30	µs	PCLK = 50 MHz
	2 Kbytes	t_{DBC2K}	-	-	0.7	ms	
Rewrite/erase cycle*1		N_{DPEC}	30000*2	-	-	Times	
Suspend delay time during writing		t_{DSPD}	-	-	120	µs	Figure 33.24 PCLK = 50 MHz
First suspend delay time during erasing (in suspend priority mode)		t_{DSESD1}	-	-	120	µs	
Second suspend delay time during erasing (in suspend priority mode)		t_{DSESD2}	-	-	1.7	ms	
Suspend delay time during erasing (in erasure priority mode)		t_{DSEED}	-	-	1.7	ms	
Data hold time*3		t_{DDRP}	10	-	-	Year	

Note 1. Definition of rewrite/erase cycle:
The rewrite/erase cycle is the number of erasing for each block. When the rewrite/erase cycle is n times (n = 30000), erasing can be performed n times for each block. For instance, when 128-byte writing is performed 16 times for different addresses in 2-Kbyte block and then the entire block is erased, the rewrite/erase cycle is counted as one. However, writing to the same address for several times as one erasing is not enabled (overwriting is prohibited).

Note 2. This indicates the minimum number that guarantees the characteristics after rewriting. (The guaranteed value is in the range from one to the minimum number.)

Note 3. This indicates the characteristic when rewrite is performed within the specification range including the minimum number.

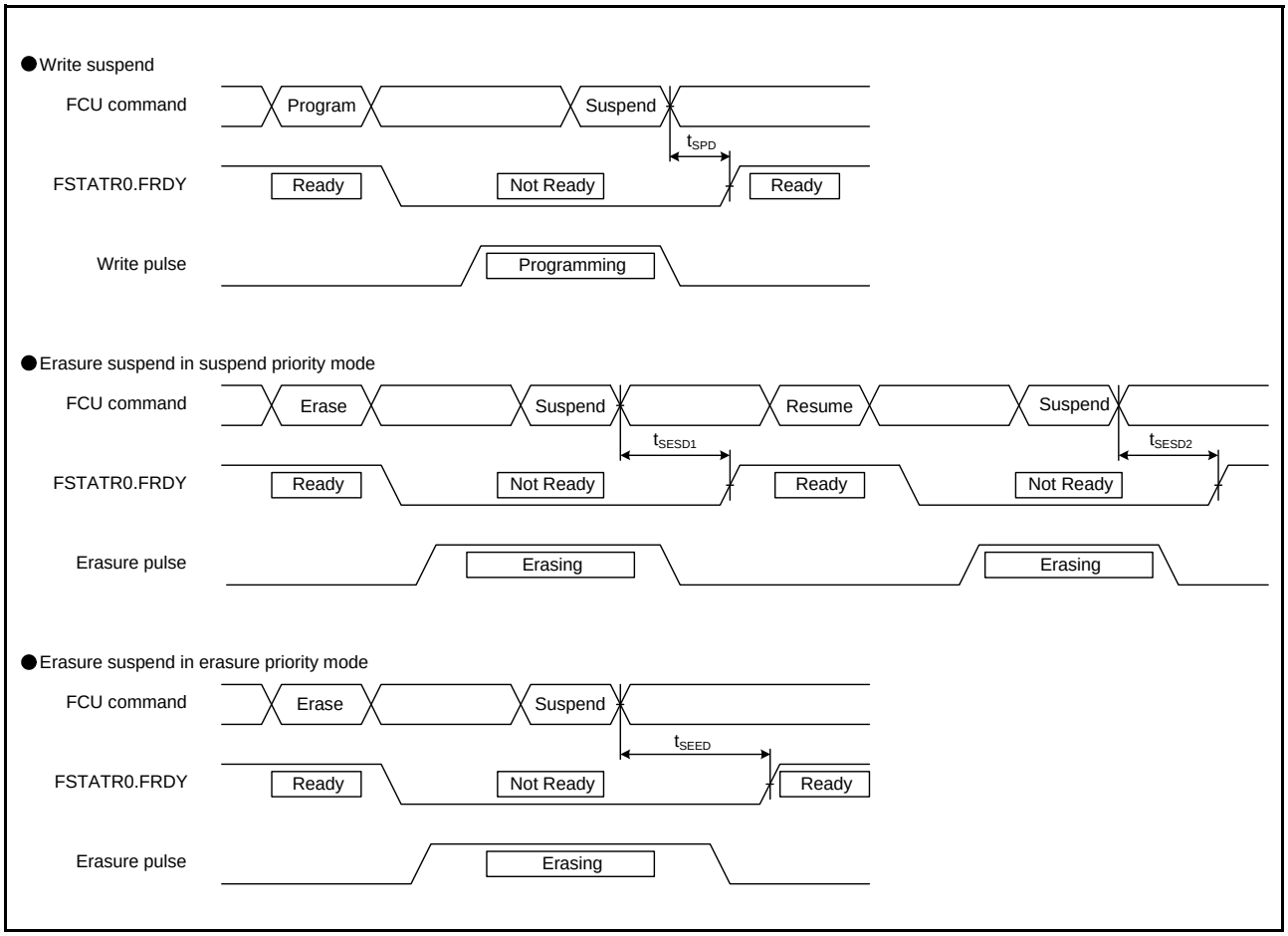


Figure 33.24 Flash Memory Write/Erase Suspend Timing

Appendix 1.Port States in Each Processing Mode

Table 1.1 Port States in Each Processing State

Port Name / Pin Name	Reset	Software Standby Mode	Deep Software Standby Mode	After Deep Software Standby Mode is Canceled (Return of Start-up Mode)	
			IOKEEP = 1/0	IOKEEP = 1*	IOKEEP = 0
Port 1	Hi-Z	Keep-O *1	Keep-O *2	Keep	Hi-Z
P20, P21	Hi-Z	Keep-O *1	Keep	Keep	Hi-Z
P22 to P24	Hi-Z	Keep-O	Keep	Keep	Hi-Z
Port 3	Hi-Z	Keep-O	Keep	Keep	Hi-Z
Port 4	Hi-Z	Keep-O	Keep	Keep	Hi-Z
Port 5	Hi-Z	Keep-O	Keep	Keep	Hi-Z
Port 6	Hi-Z	Keep-O	Keep	Keep	Hi-Z
P70	Hi-Z	Keep-O *1	Keep	Keep	Hi-Z
P71 to P76	Hi-Z	Hi-Z	Keep	Keep	Hi-Z
Port 8	Hi-Z	Keep-O	Keep	Keep	Hi-Z
P90 to P95	Hi-Z	Hi-Z	Keep	Keep	Hi-Z
P96	Hi-Z	Keep-O *1	Keep	Keep	Hi-Z
Port A	Hi-Z	Keep-O	Keep	Keep	Hi-Z
PB0 to PB3	Hi-Z	Keep-O	Keep	Keep	Hi-Z
PB4	Hi-Z	Keep-O *1	Keep	Keep	Hi-Z
PB5 to PB7	Hi-Z	Keep-O	Keep	Keep	Hi-Z
Port D	Hi-Z	Keep-O	Keep	Keep	Hi-Z
PE0, PE1	Hi-Z	Keep-O	Keep	Keep	Hi-Z
PE2	Hi-Z	[When NMI is specified as a canceling source] NMI [Other than the above] Keep-O	[When NMI is specified as a canceling source] NMI [Other than the above] Keep	[When NMI is specified as a canceling source] NMI [Other than the above] Keep	[When NMI is specified as a canceling source NMI [Other than the above] Hi-Z
PE3 to PE5	Hi-Z	Keep-O *1	Keep	Keep	Hi-Z
PG0 to PG2	Hi-Z	Keep-O *1	Keep	Keep	Hi-Z
PG3 to PG5	Hi-Z	Keep-O	Keep	Keep	Hi-Z
WDTOVF#	WDTOVF output	H	H	H	

Note: • The configuration of the I/O ports differs with the package. For the I/O ports for the respective packages, see section 14, I/O Ports.

H: High-level

L: Low-level

Keep-O: Output pins retain their previous values, and input pins become high-impedance.

*1. Input to pins in use as IRQ pins and set up as triggers for release from software standby mode is possible.

*2. Input to pins in use as IRQ pins and set up as triggers for release from deep software standby mode is possible.

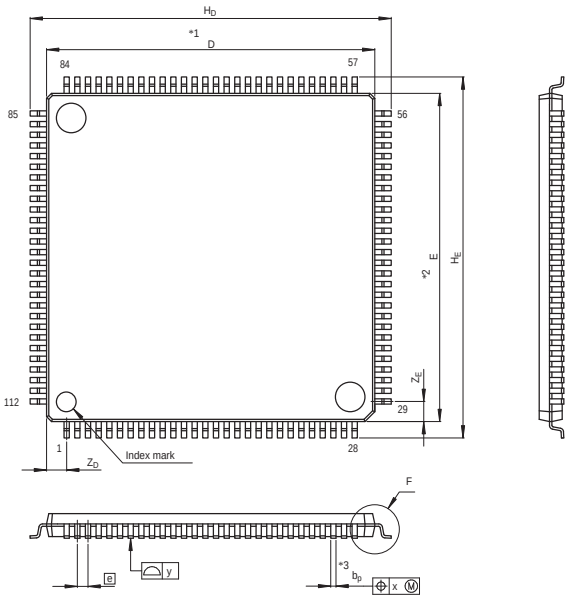
Keep: Pin states are retained during periods on software standby.

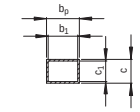
Hi-Z: High-impedance

IOKEEP = 1*: I/O pins retain their states until the IOKEEP bit in DPSBYCR is cleared to 0.

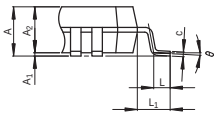
Appendix 2.Package Dimensions

JEITA Package Code	RENESAS Code	Previous Code	MASS[Typ.]
P-LQFP112-20x20-0.65	PLQP0112JA-A	FP-112E / FP-112EV	1.2g





Terminal cross section



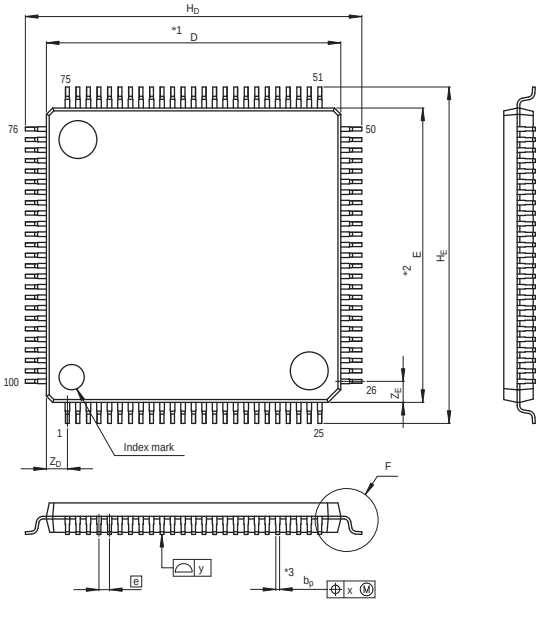
Detail F

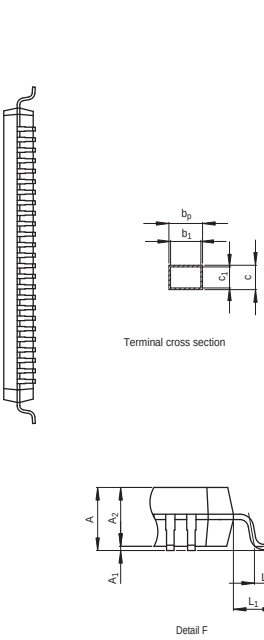
NOTE)
1. DIMENSIONS "*1" AND "*2" DO NOT INCLUDE MOLD FLASH.
2. DIMENSION "*3" DOES NOT INCLUDE TRIM OFFSET.

Reference Symbol	Dimension in Millimeters		
	Min	Nom	Max
D	19.9	20.0	20.1
E	19.9	20.0	20.1
A_2	—	1.4	—
H_D	21.8	22.0	22.2
H_E	21.8	22.0	22.2
A	—	—	1.7
A_1	0.05	0.1	0.15
b_p	0.27	0.32	0.37
b_1	—	0.30	—
c	0.09	0.145	0.20
c_1	—	0.125	—
θ	0°	—	8°
e	—	0.65	—
x	—	—	0.13
y	—	—	0.10
Z_D	—	1.225	—
Z_E	—	1.225	—
L	0.35	0.5	0.65
L_1	—	1.0	—

Figure A 112-Pin LQFP (PLQP0112JA-A) Package Dimensions

JEITA Package Code	RENESAS Code	Previous Code	MASS[Typ.]
P-LQFP100-14x14-0.50	PLQP0100KB-A	100P6Q-A / FP-100U / FP-100UV	0.6g



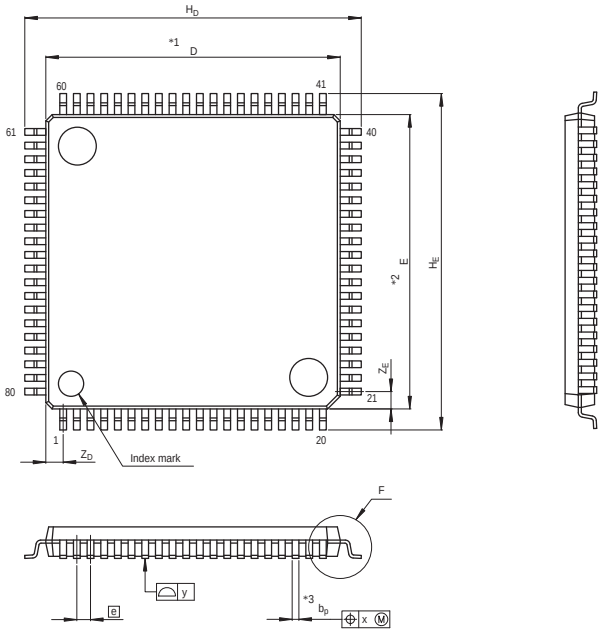


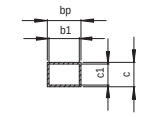
NOTE)
1. DIMENSIONS "*1" AND "*2" DO NOT INCLUDE MOLD FLASH.
2. DIMENSION "*3" DOES NOT INCLUDE TRIM OFFSET.

Reference Symbol	Dimension in Millimeters		
	Min	Nom	Max
D	13.9	14.0	14.1
E	13.9	14.0	14.1
A_2	—	1.4	—
H_D	15.8	16.0	16.2
H_E	15.8	16.0	16.2
A	—	—	1.7
A_1	0.05	0.1	0.15
b_p	0.15	0.20	0.25
b_1	—	0.18	—
c	0.09	0.145	0.20
c_1	—	0.125	—
θ	0°	—	8°
e	—	0.5	—
x	—	—	0.08
y	—	—	0.08
Z_D	—	1.0	—
Z_E	—	1.0	—
L	0.35	0.5	0.65
L_1	—	1.0	—

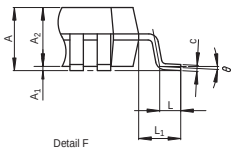
Figure B 100-Pin LQFP (PLQP0100KB-A) Package Dimensions

JEITA Package Code	RENESAS Code	Previous Code	MASS[Typ.]
P-LQFP80-14x14-0.65	PLQP0080JA-A	FP-80W / FP-80WV	0.6g





Terminal cross section



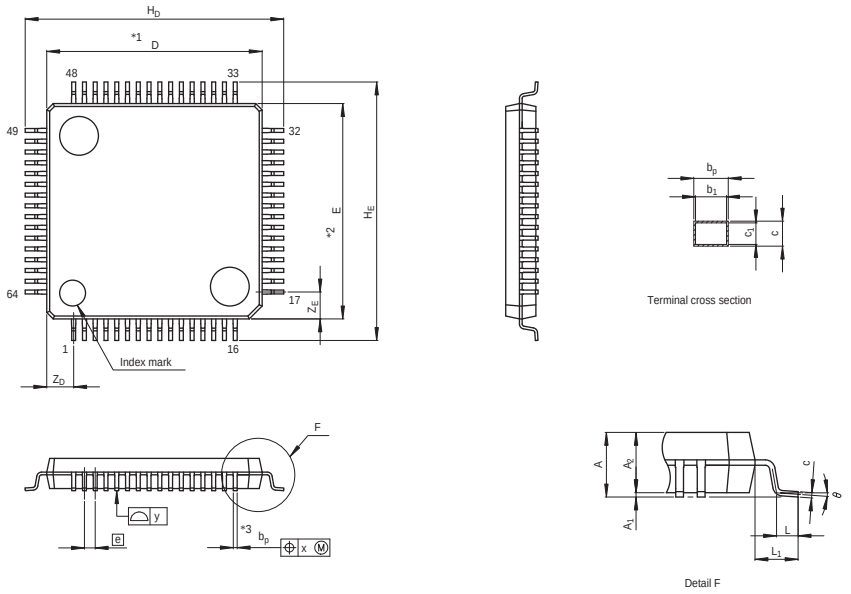
Detail F

NOTE)
1. DIMENSIONS "*1" AND "*2" DO NOT INCLUDE MOLD FLASH.
2. DIMENSION "*3" DOES NOT INCLUDE TRIM OFFSET.

Reference Symbol	Dimension in Millimeters		
	Min	Nom	Max
D	13.9	14.0	14.1
E	13.9	14.0	14.1
A_2	—	1.4	—
H_D	15.8	16.0	16.2
H_E	15.8	16.0	16.2
A	—	—	1.7
A_1	0.05	0.1	0.15
b_p	0.27	0.32	0.37
b_1	—	0.30	—
c	0.09	0.145	0.20
c_1	—	0.125	—
θ	0°	—	8°
e	—	0.65	—
x	—	—	0.13
y	—	—	0.10
Z_D	—	0.825	—
Z_E	—	0.825	—
L	0.35	0.5	0.65
L_1	—	1.0	—

Figure C 80-Pin LQFP (PLQP0080JA-A) Package Dimensions

JEITA Package Code	RENESAS Code	Previous Code	MASS[Typ.]
P-LQFP64-10x10-0.50	PLQP0064KB-A	64P6Q-A / FP-64K / FP-64KV	0.3g

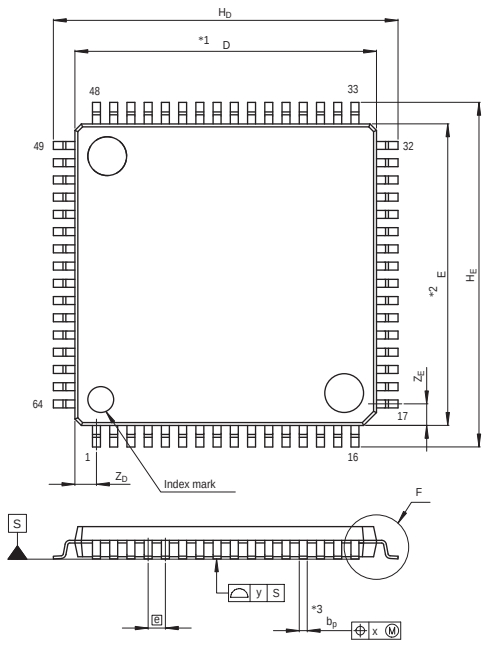


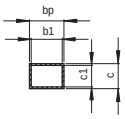
NOTE)
1. DIMENSIONS "*1" AND "*2" DO NOT INCLUDE MOLD FLASH.
2. DIMENSION "*3" DOES NOT INCLUDE TRIM OFFSET.

Reference Symbol	Dimension in Millimeters		
	Min	Nom	Max
D	9.9	10.0	10.1
E	9.9	10.0	10.1
A_2	—	1.4	—
H_D	11.8	12.0	12.2
H_E	11.8	12.0	12.2
A	—	—	1.7
A_1	0.05	0.1	0.15
b_p	0.15	0.20	0.25
b_1	—	0.18	—
c	0.09	0.145	0.20
c_1	—	0.125	—
θ	0°	—	8°
e	—	0.5	—
x	—	—	0.08
y	—	—	0.08
Z_D	—	1.25	—
Z_E	—	1.25	—
L	0.35	0.5	0.65
L_1	—	1.0	—

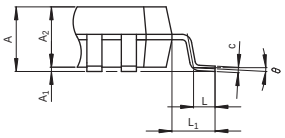
Figure D 64-Pin LQFP (PLQP0064KB-A) Package Dimensions

JEITA Package Code	RENESAS Code	Previous Code	MASS[Typ.]
P-LQFP64-14x14-0.80	PLQP0064GA-A	64P6U-A/ —	0.7g





Terminal cross section



Detail F

NOTE)
1. DIMENSIONS "*1" AND "*2" DO NOT INCLUDE MOLD FLASH.
2. DIMENSION "*3" DOES NOT INCLUDE TRIM OFFSET.

Reference Symbol	Dimension in Millimeters		
	Min	Nom	Max
D	13.9	14.0	14.1
E	13.9	14.0	14.1
A_2	—	1.4	—
H_D	15.8	16.0	16.2
H_E	15.8	16.0	16.2
A	—	—	1.7
A_1	0	0.1	0.2
b_p	0.32	0.37	0.42
b_1	—	0.35	—
c	0.09	0.145	0.20
c_1	—	0.125	—
θ	0°	—	8°
e	—	0.8	—
x	—	—	0.20
y	—	—	0.10
Z_D	—	1.0	—
Z_E	—	1.0	—
L	0.3	0.5	0.7
L_1	—	1.0	—

Figure E 64-Pin LQFP (PLQP0064GA-A) Package Dimensions

REVISION HISTORY	RX62T Group User's Manual: Hardware

Rev.	Date	Description	
		Page	Summary
0.50	Oct 05, 2010	—	First edition issued
1.00	Oct 22, 2010		1. Overview
		35 to 41	Table 1.1 Outline of Specifications: Description changed and deleted
			5. I/O Registers
		113 to 145	Table 5.1 List of I/O Registers (Address Order): Description changed and added
			13. Data Transfer Controller (DTC)
		301	13.2.1 DTC Mode Register A (MRA): Description changed
		310	Figure 13.3 Allocation of Transfer Data in the RAM Area, changed
			14. I/O Ports
		427	14.5.4 Reading Port Registers (PORT), added
			15. Multi-Function Timer Pulse Unit 3 (MTU3)
		433	Figure 15.1 Block Diagram of MTU3 (Channels 0 to 4), changed
		461	Table 15.21 TIORH (MTU3_6) to table 15.27 TIOR (MTU3_1), changed
			26. LIN Module (LIN)
		1227	Figure 26.13 LIN Error Detection Target Areas, changed
			27. 12-Bit A/D Converter (S12ADA)
		1232	Table 27.1 Specifications of A/D Converter: Description changed
		1242	27.2.2 A/D Control Register (ADCSR): Description added
		1265	27.2.13 A/D Sampling State Register (ADSSTR): Description changed
		1273	27.3.3 Analog Input Sampling and A/D Conversion Time: Description changed
		1274	Table 27.9 A/D Conversion Time, changed
		1279	27.3.8 Starting A/D Conversion with External Trigger: Description changed
			28. 10-Bit A/D Converter (ADA)
		1285	Table 28.1 Specifications of A/D Converter: Description changed
		1294	28.2.3 A/D Control Register (ADCR): Description changed
		1299	28.2.7 A/D Sampling State Register (ADSSTR): Description changed
			30. ROM (Flash Memory for Code Storage)
		1321, 1322	30.2.2 Flash Access Status Register (FASTAT): Description changed
		1345	Table 30.7 FCU Command Formats: Description changed
			32. Electrical Characteristics
		1438 to 1465	All the description added
1.10	Apr 20, 2011	All	Register symbol description, changed
		All	Name of the on-chip oscillator clock, changed
		All	One Page Summary, added
			1. Overview
		42	Table 1.3 List of Products: Operating voltage, changed
			5. I/O Registers
		105	Opening description, (1) I/O register addresses (address order): Description changed
		108 to 131	Table 5.1 List of I/O Registers (Address Order): Register symbol, changed
		132 to 162	Table 5.2 List of I/O Registers (Bit Order), changed

Rev.	Date	Description	
		Page	Summary
1.10	Apr 20, 2011		8. Clock Generation Circuit
		180	Table 8.1 Specifications of Clock Generation Circuit, changed
		186	8.9.3 On-Chip Oscillator Clock (IWDTCLK): Description changed
			9. Low Power Consumption
		192	Figure 9.1 Mode Transitions: Note 7, changed
		213	9.5.4.1 Transition to Deep Software Standby Mode: Note changed
			11. Interrupt Controller (ICU)
		246	11.2.8 Non-Maskable Interrupt Status Register (NMISR): Description changed
		250	Table 11.4 Interrupt Vector Table, changed
		257	11.4.1.1 Operation of Status Flags for Edge-Detected Interrupts: Description changed
		257	Figure 11.2 Operation of the IRi.IR Flag in the Case of Edge Detection, changed
		259	Figure 11.5 Operation of the IRi.IR Flag in the Case of a Level-Detected Interrupt, changed
			12. Buses
		270	12.2.6 Restrictions on RMPA and String-Manipulation Instructions, added
			13. Data Transfer Controller (DTC)
		297	13.4.6 Chain Transfer: Description changed
			14. I/O Ports
		All	Port register symbol, changed
		325	14.1.2.11 Port Function Register G (PFGSPI): Bit name, changed
		328	14.1.2.15 Port Function Register M (PFMPOE): Bit name, changed
		351	14.2.2.10 Port Function Register G (PFGSPI): Bit name, changed
		354	14.2.2.14 Port Function Register M (PFMPOE): Bit name, changed
		376	14.3.2.9 Port Function Register G (PFGSPI): Bit name, changed
		379	14.3.2.13 Port Function Register M (PFMPOE): Bit name, changed
		397	14.4.2.7 Port Function Register G (PFGSPI): Bit name, changed
		400	14.4.2.11 Port Function Register M (PFMPOE): Bit name, changed
			15. Multi-Function Timer Pulse Unit 3 (MTU3)
		All	Register symbol description of MTU3, changed
		418 to 421	15.2.8 Timer Buffer Operation Transfer Mode Register (TBTM): Bit description, changed
		481	15.2.28 Timer Waveform Control Registers (TWCRA and TWCRB): Bit description, changed
		518	Figure 15.26 Example of PWM Mode Setting Procedure, changed
		572	Figure 15.83 Example of Procedure for Specifying A/D Converter Start Request Delaying Function: Figure title, changed
			16. Port Output Enable 3 (POE3)
		All	Register symbol description of MTU3, changed
			17. General PWM Timer (GPT)
		688	17.2.2 General PWM Timer Hardware Source Clear Control Register (GTHSCR): Bit name, changed
		689	17.2.3 General PWM Timer Hardware Source Clear Control Register (GTHCCR): Description added
		690	7.2.4 General PWM Timer Hardware Start Source Select Register (GTHSSR): Description added
		707	17.2.18 General PWM Timer Control Register (GTCR): Address changed and description added
			19. Watchdog Timer (WDT)
		831	19.5.1 (1) Writing to TCNT Counter, TCSR Register, and RSTCSR Register, changed
		832	19.5.2 (1) Reading from TCNT Counter, TCSR Register, and RSTCSR Register, changed

Rev.	Date	Description	
		Page	Summary
1.10	Apr 20, 2011		20. Independent Watchdog Timer (IWDT)
		All	The symbol of the on-chip oscillator clock is changed from OCOCLK to IWDTCLK.
			21. Serial Communications Interface (SCIb)
		All	The register symbol in smart card interface is changed to "SMCI".
		All	The section configuration is separated according to the mode.
		843	Table 21.1 Specifications of SCI: Note added
		845	Table 21.2 Pin Configuration of SCI/SMCI: Title and contents, changed
		867	Figure 21.5 Sample SCI Initialization Flowchart (Asynchronous Mode), changed
		868	Figure 21.6 Example of Operation for Serial Transmission in Asynchronous Mode (Example with 8-Bit Data, Parity, One Stop Bit), changed
		870	Figure 21.8 Example of SCI Operation for Serial Reception in Asynchronous Mode (Example with 8-Bit Data, Parity, One Stop Bit), changed
		875	Figure 21.13 Example of SCI Reception (8-Bit Data/Multi-Processor Bit/One Stop Bit), changed
		879	Figure 21.17 Example of SCI Initialization Flowchart (Clock Synchronous Mode): Note added
		880	Figure 21.18 Example of Operation for Serial Transmission in Clock Synchronous Mode, changed
		881	Figure 21.19 Example of Serial Transmission Flowchart (Clock Synchronous Mode): Note added
		882	Figure 21.20 Example of Operation for Serial Reception in Clock Synchronous Mode, changed
		886	21.3 Smart Card Interface Mode, Separated and added
		901	Figure 21.28 Data Retransfer Operation in SMCI Transmission Mode, changed
		904	Figure 21.31 Data Retransfer Operation in SMCI Reception Mode, changed
		907	21.4 Noise Cancellation: Description changed
			23. I^2C Bus Interface (RIIC)
		924	Figure 23.2 Connections to the External Circuit by the I/O Pins (I^2C Bus Configuration Example), changed
		951	23.2.11 Slave Address Register Ly (SARLy): Bit name, changed
		952	23.2.12 Slave Address Register Uy (SARUy): Bit name, changed
		954	23.2.14 I^2C Bus Bit Rate High-Level Register (ICBRH): Description on the duty ratio, changed
		963	23.3.4 Master Receiver Operation, changed
		965	Figure23.10 Example of Master Reception Flowchart (7-Bit Address Format), changed
		967	Figure23.13 Master Receive Operation Timing (3) (when RDRFS=0), changed
		996	23.11.2 Extra SCL Clock Cycle Output Function: Description changed
		1002	23.15.2 Setting Input Buffer Control Register: Description changed
			24. CAN Module (CAN)
		All	Register symbol description of CAN registers, changed
		1006	Table 24.3 Registers of CAN Module, changed
		1013	24.2.3 Mask Register I (MKRi): Bit name, changed
		1017	Table 24.5 Mailbox Memory Mapping, changed
		1027	24.2.9 Receive FIFO Control Register (RFCR): Bit name, changed
		1051	24.2.24 (2) Self-Test Mode 0 (External Loopback): Description changed
		1063	24.7 Reception and Transmission: Description changed
			25. Serial Peripheral Interface (RSPI)
		1079	25.2.5 RSPI Data Register (SPDR): Bit name, changed
		1080	25.2.6 RSPI Sequence Control Register (SPSCR): Description changed
		1116	Table 25.9 Relationship between Non-Normal Transfer Operations and RSPI Error Detection Function, changed

Rev.	Date	Description	
		Page	Summary
1.10	Apr 20, 2011	1136	Figure 25.36 Example of Initialization Flowchart in Slave Mode (Clock Synchronous Operation), changed
			26. LIN Module (LIN)
		All	Register symbol description of LIN registers, changed
		1165	26.3.2 LIN Operation Mode: Description changed
			27. 12-Bit A/D Converter (S12ADA)
		All	Register symbol description of S12ADA registers, changed
		1188	Table 27.3 Input Pins of A/D Converter: Note changed
		1203	27.2.5 A/D Start Trigger Select Register (ADSTRGR): Bit description, changed
		1216	27.2.12 Comparator Interrupt Select Register (ADCMPSEL): Symbol of b9, changed
		1232	27.5.1 Module Stop Function Setting to 27.5.9 Point for Caution Regarding Countermeasures for Noise: Description order, changed
		1233	27.5.5 Permissible Impedance of Signal Sources: Description changed
		1233	Table 27.10 Specifications of Analog Pins, changed
		1233	27.5.6 Realizing High-Speed Conversion, deleted
		1234	27.5.8 Point for Caution Regarding Board Design: Description added
			28. 10-Bit A/D Converter (ADA)
		1238	Table 28.3 Input Pin for A/D Converter: Symbol changed
		1239	Table 28.4 Registers of A/D Converter: Symbol changed 28.2.2 A/D Control/Status Register (ADCSR): Description
		1261	28.6.10 Realizing High-Speed Conversion, deleted
			30. ROM (Flash Memory for Code Storage)
		1278	Table 30.4 States of FCMDR after Receiving Each Command, changed
		1312	Table 30.9 Error Protection Types (Types Dedicated to ROM and Types Common to ROM and Data Flash), changed
		1339	30.12 (4) Reset during Programming or Erasure: Description added
			31. Data Flash Memory (Flash Memory for Data Storage)
		1352	31.2.9 Data Flash Blank Check Control Register (DFLBCCNT): Bit table, changed
		1362	Table 31.5 FCU Commands for Use with Data Flash Memory, changed
			32. Electrical Characteristics
		1375	Table 32.3 DC Characteristics (2): Note 3, changed
		1381	Table 32.7 Control Signal Timing, changed
		1383	Table 32.9 Timing of On-Chip Peripheral Modules (2), changed
		1389	Figure 32.17 MTU3 Clock Input Timing, changed
		1391	Table 32.13 10-Bit A/D Conversion Characteristics, changed
		1392	Table 32.14 12-Bit A/D Conversion Characteristics, changed
1.20	Oct 04, 2011		8. Clock Generation Circuit
		184	8.3.1 Connecting a Crystal Resonator, changed
		184	Figure 8.3 Equivalent Circuit of Crystal Resonator, changed
			9. Low Power Consumption
		219	9.6.6 Conflict between Transition to Deep Software Standby Mode and Interrupt, changed
			11. Interrupt Controller (ICU)
		229	Table 11.1 Specifications of the Interrupt Controller, changed
		230	Figure 11.1 Block Diagram of Interrupt Controller, signal name changed
		245	11.2.7 IRQ Control Register n (IRQCRn), description changed
		246	11.2.8 Non-Maskable Interrupt Status Register (NMISR), description changed
		247	11.2.9 Non-Maskable Interrupt Enable Register (NMIER), description changed

Rev.	Date	Description	
		Page	Summary
1.20	Oct 04, 2011	263	11.5 Non-Maskable Interrupt Operation, description changed
			13. Data Transfer Controller (DTC)
		301	Table 13.10 Execution Cycle of the DTC, changed, note7 added
			14. I/O Ports
		331 to 335	Table 14.6 Output Enable Settings for Each Port (112-pin LQFP), RSPI in PB0 setting changed
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